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ABSTRACT

In 1989, the Texas Alliance for Science, Technology, and Mathematics Education began placing teachers at industry sites as part of its Texas Teacher Internship Program (TTIP). TTIP is a competitive program for science, technology, and mathematics teachers who serve as summer interns at industry and university sites in order to experience real-world applications of the subjects they teach. In 1996, a total of 12 teachers interned at seven sites and were required to develop a curriculum implementation plan (CIP) which illustrated how they would translate the summer experience into the subsequent year's classroom curricula. This document is a compilation of the curriculum implementation plans developed by the teachers. Topics include measurement errors, physical science/environmental science, composite science, biology, chemistry, ecology, technology, astronomy, geology, life science, mathematics, and endocrinology. (JRH)

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# T T I P

## Texas Teacher Internship Program

Texas A&M University

Brian T. Walenta, Editor

# 1996 CURRICULUM IMPLEMENTATION PLANS

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Texas Alliance For Science, Technology &
Mathematics Education

## About the Alliance

The Texas Alliance for Science, Technology and Mathematics Education is a statewide, nonprofit organization whose membership includes representatives from K-12 schools, colleges and universities, businesses and industry, professional and civic organizations, and government agencies. By fostering partnerships between schools and the private sector, the Texas Alliance works to:

- improve student literacy and competency in science, mathematics and technology education; and
- assist teachers in developing curricula with emphasis on "real world" applications and problem-solving skills.

**For membership and educational program information, contact:**

**Texas Alliance for Science, Technology & Mathematics Education**
**Texas A&M University**
**EDCI, College of Education**
**College Station, Texas 77843-4232**
**PH: 409/845-0825 FAX: 409/845-9663**

**Dr. Robert K. James, Director**
**Maureen Stewart, Development Coordinator**
**Brian Walenta, TTIP and Symposium Coordinator**
**Dwight Bohlmeyer, BTEP Coordinator**
**Jeannine Kantz, BTEP Coordinator**
**Craig Wilson, First STEP Coordinator**
**Debbie Jensen, TENET Project**
**Kristin Hamm, SALISH Project**
**Kay Labuda, SALISH Project**

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*The Texas Teacher Internship Program is a project of the Texas Alliance for Science, Technology and Mathematics Education, under the direction of Dr. Robert K. James, EDCI, College of Education, Texas A&M University, College Station, TX 77843-4232.*

*Funding for the project is provided by the participating industries. Publication of the curriculum plans for 1996 was provided by Texas Utilities Electric located in Dallas, Texas.*

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# TTIP Program Mission

In 1989, the Texas Alliance for Science, Technology and Mathematics Education began placing teachers at industry sites as part of its now-successful program, the Texas Teacher Internship Program (TTIP—formerly Teacher-In-Industry). In the seven years of the program, the numbers of both teacher participants and internship sponsors have increased steadily. Since its inception, over 150 teachers have interned at 45 company, university and government agency sites. With each teacher affecting an average of 150 students per year, over 72,000 Texas students have been directly impacted by TTIP to date.

TTIP is a competitive program for science, technology and mathematics teachers who serve as summer interns at industry and university sites in order to experience "real world" applications of the subjects they teach. Teacher interns are mentored by a scientist or engineer, and work on a project(s) for an 8 week internship period.

The objectives of the program are to:

- Provide teachers with relevant, timely information about science, technology and mathematics applications so they can better prepare students for the future.
- Establish interactive partnerships between industry and teachers—sharing resources and curriculum improvements, and strengthening state and community networks throughout the educational system.
- Increase teachers' awareness of industry expectations and career opportunities to better inform and motivate students regarding careers in science, technology, and mathematics.

In 1996, a total of 12 teachers interned at seven sites. Each teacher was required to develop a curriculum implementation plan (CIP) which was to illustrate how they would translate the summer experience into the subsequent year's classroom curricula. The Alliance staff provided teachers with suggestions for developing the CIPs during site visits.

We are pleased with the success of the 1996 program and hope that you find the CIPs helpful in planning new activities for your students.

For more information on the Texas Teacher Internship Program, please write or call:

Brian T. Walenta, TTIP Coordinator
or
Robert K. James, Director
c/o Texas Alliance
EDCI, College of Education
Texas A&M University
College Station, TX 77843-4232
PH: 409/845-0825 FAX: 409/845-9663

# Acknowledgements

The Texas Alliance for Science, Technology and Mathematics Education would like to thank the program's supporters for providing the opportunity for teachers to experience "real-world" applications of their teaching fields. Many thanks to the industry coordinators and mentors involved with the 1996 Texas Teacher Internship Program.

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**Exxon Chemical, Baytown**
Doug Deason
Dr. Brigitte Laki

**Fina Research & Development Technical Center, Deer Park**
Dr. Jose Sosa
Lu Ann Kelly

**Texas A & M University, College Station**
Biochemistry Department
Dr. Bruce McDonald
Dr. Ed Funkhouser

Center for Chemical Characterization and Analysis
Dr. E.A. Schweikert

**Texas Parks and Wildlife Department, Austin**
Bob Murphy
Nancy Herron
Steven Hall
Kathryn Hampton
Scotty Oliver

**Texas Utilities Electric, Dallas**
Orlan Ihms

**University of Texas Medical Branch, Galveston**
Dr. Peter Bowman
Dr. Todd Miller
Dr. William Buford
Dr. Chandra Yallampalli

**University of Texas Southwest Medical Center, Dallas**
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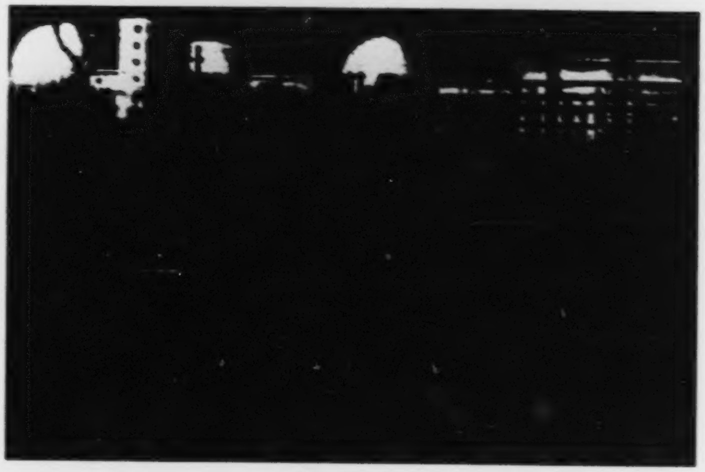
1996 Evaluation Information

Intern Information

**Ann T. Kelley**
**Composite Science, Chemistry**
**Stephen F. Austin High School, Houston ISD**

**Exxon Chemical, Baytown**
**Dr. Brigitte Laki, Mentor**



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# CURRICULUM IMPLEMENTATION PLAN

## MEASUREMENT ERRORS

NAME: Ann T. Kelley

INTERNSHIP: Exxon Chemical Americas, Baytown, Texas

SCHOOL: Stephen F. Austin Senior H.S., Houston, TX

PRIMARY SUBJECT: ESL Physical Science, Grades 9 through 12

ACTIVITIES:

(1) "THE LENGTH OF A PESTLE: A Class Exercise in Measurement and Statistical Analysis"

(2) "A SIMPLE BUT EFFECTIVE DEMONSTRATION FOR ILLUSTRATING SIGNIFICANT FIGURE RULES WHEN MAKING MEASUREMENTS AND DOING CALCULATIONS"

(3) "MORE ON THE QUESTION OF SIGNIFICANT FIGURES"

(4) "MEASURING WITH A PURPOSE: Involving Students in the Learning Process"

(5) "A SIMPLE LABORATORY EXPERIMENT USING POPCORN TO ILLUSTRATE MEASUREMENT ERRORS"

(6) "INTRODUCTORY LABORATORY EXERCISES"

(7) "A PAPER VERNIER SCALE FOR VARIOUS LABORATORY EQUIPMENT"

(8) "TEACHING DILUTIONS"

(9) "SIGNIFICANT FIGURES"

OBJECTIVES: To provide chemistry teachers with interesting activities for teaching correct measuring techniques, and to impress on chemistry students an awareness of the importance of minimizing measurement errors

SUMMARY: If the amount of something is not known (only that SOME is present) it is hard to judge the significance of the result.

Even where a qualitative answer is required, quantitative methods are used to obtain it.

Errors that occur in quantitative studies are extremely important. NO QUANTITATIVE RESULTS ARE OF ANY VALUE UNLESS THEY ARE ACCOMPANIED BY SOME ESTIMATE OF THE ERRORS INHERENT IN THEM.

A knowledge of experimental errors is crucial to the proper interpretation of the results. This involves a comparison of the experimental value with an assumed or reference value.

Problems arise in the comparison of two (or more) sets of results.

In order to minimize errors, one must ask the following questions:

> Are the two average values significantly different, or are they indistinguishable within the limits of experimental error?
>
> Is one method significantly less error-prone than the other?
>
> Which of the mean values is actually closer to the truth?

Many analyses are based on graphical methods. Instead of making repeated measurements on the same sample, a series of measurements on a small group of standards which have known concentrations covering a considerable range can be made. In this way a calibration curve can be set up that can be used to estimate the concentrations of test samples studied by the same procedure.

NOTE: In practice, however, all the measurements subject to error.

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## TERMINOLOGY

**GROSS ERRORS:** these are so serious that there is no real alternative to abandoning the experiment and making a fresh start.
Examples: bad reagent; contamination; instrument breakdown.

**RANDOM ERRORS:** individual results fall on both sides of the average value.
Consequence: these affect the PRECISION, or REPRODUCIBILITY of an experiment.

**SYSTEMATIC ERRORS:** all results are in error in the same sense
Consequence: these affect the ACCURACY of an experiment.

**REPRODUCIBILITY:** "between-run" precision (different conditions, different reagents, different times).

**REPEATABILITY:** "within-run" precision (same equipment, same reagents, same circumstances; done in a short time span).

Note: WEIGHING PROCEDURES are normally associated with very small RANDOM errors (when using a "four-place" balance, but with appreciable SYSTEMATIC errors (moisture on vessel surfaces; failure to cool heated vessels to the temperature of the balance; damaged weights; buoyancy effect of the atmosphere).

VOLUMETRIC procedures incorporate several sources of SYSTEMATIC error: drainage (pipettes and burettes); calibration (volumetric equipment is usually calibrated at 20 degrees Celsius, but laboratory temperatures may vary); "indicator errors" (some indicators change colors over a pH range); "last-drop" errors (it is not known how much of the last drop added in a titration is actually needed to reach the end point).

Table 1.2 — Summary of definitions

| Types of error | |
|---|---|
| Random | Systematic |
| Affect precision | Affect accuracy |
| Within-run precision is repeatability | Proximity to the truth |
| Between-run precision is reproducibility | |
| Also known as indeterminate errors | Also known as determinate errors |

**COLLABORATIVE TRIALS:** in many such trials involving different laboratories, results of experiments conducted under meticulous conditions, using the experimental procedures and the same types of instrument, the variation in the results often greatly exceeds that which could be reasonable expected from random errors.

Consequence: many studies of the methodology of collaborative trials, and of the statistical evaluation of their results.

**CHEMOMETRICS:** the application of mathematical methods to the solution of chemical problems of all types.

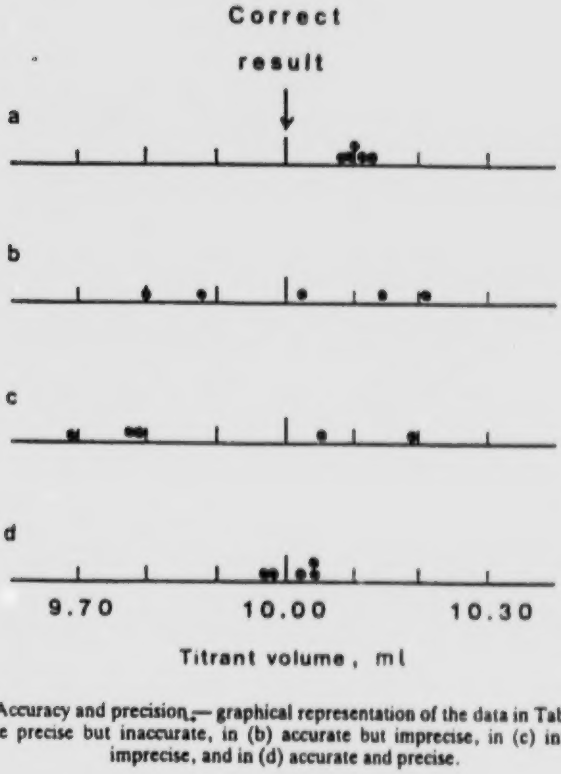

Fig. 1.1 — Accuracy and precision — graphical representation of the data in Table 1.1. In (a) the data are precise but inaccurate, in (b) accurate but imprecise, in (c) inaccurate and imprecise, and in (d) accurate and precise.

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# The Length of a Pestle

## A Class Exercise in Measurement and Statistical Analysis

**James E. O'Reilly**
University of Kentucky, Lexington, KY 40506

At any number of points in chemistry and science curricula, students come into formal contact with the principles of measurements and the statistical analysis of data. In beginning courses, this may entail discussion of significant figures and calculating an average value and its associated standard deviation. Later on, the propagation of error and various techniques of hypothesis testing may be covered.

Unfortunately, far too many students seem to get through chemistry courses without acquiring a basic understanding and appreciation of the concepts of measurement science—just what a measured number means, and how good it is. Statistics seems to be a set of theoretical constructs that has no relation to what one does in the laboratory. Where have we erred?

Very few class or laboratory exercises have been described in THIS JOURNAL in which measurement error was the focus (*1–4*). It is the purpose of this report to outline an extremely simple class exercise—measuring the length of an object—as a concrete paradigm of the entire process of making chemical measurements and treating data therefrom. This exercise strives for relevance by giving every student a stake in the data. It is much more interesting to collect and analyze one's own data. The measurements are so simple that students do not get lost in what is being done; yet there are enough subtleties to intrigue even the most advanced students, if appropriately presented. A number of very basic and some very subtle points can be illustrated in a concrete manner and, presumably, driven home with a degree of finality. The creative instructor can adapt this exercise to fit the level of the students involved and the statistical topics discussed in a particular course.

### Procedure

The equipment to conduct the exercise was provided in a common area: a standard agate pestle about 6 cm in length, an ordinary wooden meter stick, a finely scribed 15-cm stainless-steel ruler, and a stainless-steel vernier caliper. Only one of each was provided, so all students used exactly the same equipment. In order to standardize the measurement protocol, students were instructed to measure the length of the pestle once with the Meter stick, then with the Ruler, and finally with the Caliper; this procedure was to be repeated for the required number of replicates, 10 in our case. Students were told that, if they discovered an error in an earlier measurement during the process, *not* to change the value or replace it with an additional measurement. There was a valuable point to even grossly erroneous measurements in this exercise. (Care was taken not to embarrass these students later.) Thus, each student performed exactly 30 measurements in the sequence M → R → C → M → R. . .

Each student was provided a columnar data sheet on which to record results. Columns were headed Meter, Ruler, and Caliper left to right; and replicates were listed vertically to reinforce the order of the experiments. In an effort to minimize human bias, students were asked to do their best to "forget" earlier results, and data sheets were returned immediately to the instructor.

The data were compiled by the instructor and entered onto a microcomputer using a data-base-management and a statistics program to facilitate data treatment. Each student was provided a printout of the class results, along with a notation of which numbered analyst he was. The students were asked to perform certain calculations and statistical tests as topics were discussed (mean, pooled variance, *F*- and *t*-tests, analysis of variance). Printouts were revised and redistributed so students could check their results.

A subset of results from one class, a beginning graduate-level class in "advanced analytical chemistry", is presented in the table, exactly as transcribed from students' data sheets.

**Length of an Agate Pestle (cm)[a]**

| Instrument | Analyst | Replicate Number<br>1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Meter Stick | 1 | 6.0 | 5.95 | 6.0 | 5.90 | 6.0 | 6.0 |
| | 2 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| | 3 | 5.7 | 5.7 | 5.6 | 5.7 | 5.7 | 5.7 |
| | 4 | 5.95 | 6.00 | 6.00 | 6.05 | 6.00 | 5.9 |
| | 5 | 5.9 | 6 | 6 | 6.1 | 6.1 | 6.2 |
| | 6 | 6.0 | 5.9 | 6.0 | 6.1 | 6.0 | 6.0 |
| | 7 | 6.0 | 6.1 | 6.0 | 5.9 | 6.0 | 5.9 |
| Steel Ruler | 1 | 5.9 | 5.95 | 5.95 | 5.95 | 5.90 | 5.95 |
| | 2 | 6.98 | 6.95 | 6.00 | 6.05 | 6.03 | 6.04 |
| | 3 | 5.7 | 5.7 | 5.7 | 5.8 | 5.7 | 5.7 |
| | 4 | 6.00 | 5.95 | 5.99 | 5.98 | 6.01 | 6.02 |
| | 5 | 6 | 6 | 6.1 | 6.1 | 6.1 | 6.0 |
| | 6 | 6.1 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| | 7 | 5.9 | 5.9 | 6.1 | 6.0 | 5.9 | 5.9 |
| Vernier Caliper | 1 | 6.02 | 6.03 | 6.02 | 6.03 | 6.03 | 6.02 |
| | 2 | 6.02 | 6.02 | 6.02 | 6.02 | 6.02 | 6.02 |
| | 3 | 6.3 | 6.3 | 6.2 | 6.2 | 6.2 | 6.2 |
| | 4 | 6.02 | 6.02 | 6.01 | 6.03 | 6.00 | 6.00 |
| | 5 | 6.01 | 6.02 | 6.02 | 6.02 | 6.02 | 6.02 |
| | 6 | 6.3 | 6.2 | 6.2 | 6.3 | 6.02 | 6.03 |
| | 7 | 6.020 | 6.02 | 6.02 | 6.02 | 6.02 | 6.02 |

[a] The values are a selected subset of 180 data taken by 16 analysts, 10 replicates ea

### Significant Figures and Measurement Error

Even a casual inspection of the data reveals one distressing point: Even with chemistry graduate students, the concept of significant figures is not universally understood to the point of routine and automatic application to a set of measurements. Consider Analyst 5, for example. It seems apparent he had decided the length measured by the meter stick could be reported each time to no better than 0.1 cm, the steel ruler to 0.05 cm, the caliper to 0.01 cm. Certainly reasonable. However, the point that reporting a "6" as a *measured quantity* is not the same as reporting a "6.0" had not been effectively mastered.

Exactly how finely measurements could be made was a point of some class discussion. The majority of one particular class, for example, initially felt that measurements with the meter stick and the ruler could be made to only 0.05 cm. This was evident on classifying the data and plotting a histogram: a marked bimodal distribution with maxima at 6.00 and 6.05 cm.

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Some thought went into selection of the pestle as the measurement object. It was a single object, thus there was no natural variation among units such as the weights of a series of pennies. Given the precision of the measurements, there was also no natural variation in the length as is encountered, for example, in the diameter of an ordinary marble (*1*). The errors encountered in this exercise all can be ascribed to the natural imprecision of the measurement tools themselves and the analysts' use of the devices. The meter stick, for example, happened to have an additional millimeter or so of wood beyond the zero mark, thus complicating measurements.

On the other hand, the pestle was perhaps fortuitously chosen. One end was rounded, and it was tapered: thus the length could not be properly measured by simply laying it flat on the ruler or meter stick. The end of the steel ruler was flush with its zero mark, and the pestle was flat on one end (most pestles are rounded on both ends). Thus the more creative quickly saw they could stand the pestle on a flat bench top or table, put the ruler behind it, and measure the length fairly precisely by sighting across the top of the pestle, much as a buret is read.

The point of analogy in all this is that in an analytical chemical measurement there are also often several tools (methods) applicable to the problem at hand. Some are better than others. Each needs to be used properly, and has its own set of inherent limitations. Any method, no matter how simple it may seem, can be creatively applied in a particular situation.

### Spurious Data and Rejection of Results

Even for a process as straightforward as measuring the length of an object, about 4% of the total data reported (16 students by 10 replicates each) was clearly spurious. Most of these arose from transcription errors or misreading of the vernier caliper, a not-uncommon difficulty (*5*). See, for example, Analyst 2 using the Ruler, Analysts 3 and 6 using the Caliper. If the more or less typical practice of doing only three replicates on an unknown were to have been followed, the frequency of spurious results rose to about 6%.

While in this instance students generally became aware of "wrong" values quickly and would not have reported them if not constrained to do so, this is clearly not the case in most chemical measurements. Without proper attention to the details of the entire measurement process, and careful data analysis, "erroneous" results are seldom apparent. Moreover, the clearly spurious results in our class exercise are obvious primarily because there were three 16 × 10 grids of values of the same measured quantity. Seldom, in real life, does an analyst have such a cornucopia of data. This is a very important point for students who may soon be required to judge the reliability of data and make decisions based on data supplied by others, as in the case of a laboratory supervisor. If nothing else, this class exercise should serve to instill a proper suspicion of anyone's data, including one's own.

Appropriate statistical tests (*Q*-test, $3\sigma$ criteria, etc.) can be used to reject spurious data individually, or all the results from a particular analyst by comparing analyst means. For example, the caliper measurements of Analysts 3 and 6 could be rejected with high confidence when all 160 data are considered. Moreover, the measurement process here is so straightforward that most of the spurious results can be "corrected" with a fairly high degree of confidence. For example, reported values of 6.3 and 6.2 cm clearly arise from misreading of the vernier and are really supposed to be 6.03 and 6.02 cm. With reasonable confidence, therefore, these data can be corrected and a symmetrical grid (no empty cells) of data preserved to facilitate later statistical calculations and testing. It is important to stress, however, that in the vast majority of all chemical measurements such "correction" is not possible nor permissible: The data are there and are assumed to be correct unless rejectable by some valid statistical process. It is seldom possible to figure out what went wrong once results have left the hands of the original analyst.

### Precision and Accuracy

Each student can calculate his or her own mean and standard deviation for each of the three tools, and compare these to the appropriate class values using *t*- and *F*-test procedures. Class mean and median values, pooled standard deviations, etc., can be calculated using all the data and, after rejecting or "correcting" outliers, compared. Does one tool yield significantly more precise or accurate results? Most beginning students would assume the mean of the vernier-caliper measurements, which is much more precise (in our case, $s_p = \pm 0.006$ cm with outliers rejected), automatically implies the highest degree of accuracy. This is a good time to point out that, barring suitable calibration, the average from the vernier caliper may well be no closer to the "true value" of the length than that using the meter stick.

Provided with a complete listing of all students' standard deviations, for example, it can now be made very clear and concrete how a pooled standard deviation is a better approximator of the true variation to be expected for the measurement method. Standard deviations with the steel ruler, for example, ranged from ±0.015 to ±0.075 cm, a difference factor of 5. The class pooled standard deviation was ±0.040 cm. What is the "best" estimate to be expected for the typical person performing this measurement? Additionally, the coarseness of the scale readability of the caliper (0.01 cm) was larger than the repeatability of some students' measurements, leading to an erroneous precision estimate. An average of 6.02 ± 0.00 cm cannot indicate a total absence of error, and complicates later statistical evaluation. A measured value without some estimate of its uncertainty is meaningless.

It is embarrassing for any scientist to be confronted with evidence of personal bias or "operator error" in a measurement. Consider the meter-stick results for Analysts 2 and 3. One consistently measured 6.0 cm, the other 5.7 cm: for 10 replicates each, 6.0 ± 0.0 and 5.69 ± 0.03 cm. Clearly a systematic difference exists. Additionally, as discussion and the statistics indicated that the meter stick could really estimate the length to no better than perhaps 0.05 cm per reading, both standard deviations are suspect.

### Advanced Concepts

Depending on the class goals, various advanced statistical concepts can be discussed. For example, we performed various ANOVA calculations on the data. It was very interesting, and quite sobering, to see the degree of analyst-to-analyst variation in a task as simple as length measurement: With the meter stick and steel ruler, the calculated *F*-ratios were about 40 for, in our case, 144 and 15 degrees of freedom—a vanishingly small probability that there were not significant systematic differences among analysts. It should be pointed out that, for proper hypothesis testing, the order of the measurements should have been randomized. In this exercise, they were not. Another interesting result was that the variances in length using the vernier caliper were so small that calculator (*6*) and computer round-off errors would often produce a spurious *F*-value.

Students can be asked to use $\chi$-square procedures to see if the readings follow a Gaussian distribution (no), or exhibit a number bias in the terminal digit (yes) (*4,7,8*), or to apply the Youden sum-rank test, the Dixon test, or some other sophisticated test to reject outliers.

### Student Response

Overall student response to this exercise was quite positive. The data were "real", not just some numbers in a

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textbook problem, and taking the data required only about 15 min per student. Students particularly liked having one set of data on which to apply many statistical processes. The major complaint was that, with the large number of data available, the calculations sometimes became quite tedious. The exercise is best suited to a small group of students; in a larger class, it would be best to divide the students into groups, decrease the number of replicate measurements, and/or take a subset of the results for discussion.

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## CAI Lab on Measurement and Error for High School Chemistry

**Patrick Lang**
Bristol Central High School
Bristol, CT 06010

In the lab, students gather the data needed to find volume and density of a wooden block along with the volume and density of the water that fills a beaker. A meter stick is used to measure the block's length, width, and thickness. Since the block is not a perfect rectangular solid, each of the three dimensions is measured in more than one place on the block. An average is then calculated for each dimension. A vernier caliper is used to measure the inside diameter and height of the empty beaker. Again, both the diameter and height are measured in more than one place on the beaker and an average for each is calculated. Also the mass of the empty beaker, the mass of the beaker full of water, and the mass of the block are determined on a balance.

Students type their lab data for the block into the computer program. The program displays and explains each calculation with the students' data as it shows how to calculate the volume and density of the wooden block, keeping track of the uncertainty. Then, as an assignment, the student must calculate the volume and density of the water contained in the beaker, also keeping track of the uncertainty. Instantaneous printout of the calculations upon input of the data allows a maximum of 20 high school students working in pairs to take all the measurements and see all the calculations on their block measurements in one 42-min lab period.

Deviations in the measurement result from the irregularities in the block, which is rough-cut from a two-by-four, and because the measurement is precise only to two decimal places. In order to adjust for the deviation, the length, width, and thickness are each measured in four different places on the block. If measured properly, rarely are two measurements of the same dimension equal. The four lengths, four widths, and four thicknesses are entered into the computer which then displays for each dimension the calculation of the mean, the absolute deviation from the mean, and the mean deviation. Also displayed are the calculations for maximum, minimum, mean, and deviation from the mean of volume and density. The magnitude of the length, width, thickness, volume, and density is the mean value for each. The uncertainty in each value is expressed as + or − the mean deviation and can be observed to increase as calculations are done. This magnification that occurs as successive calculations are carried out leads to a discussion of the rules for significant figures to be used during the rest of the course.

The diameter and height of a 250-ml beaker are measured four times each. Then the mass of the beaker both empty and full of water is determined. As an assignment, the student must do the same calculations for the water as the computer did for the block.

This lab has been used as the introductory lab for the past 11 years in a high school chemistry course. For the past three years the lab has utilized the computer to help the students perform the calculations. In the past the students did not finish the calculations in one lab period, and in many cases, experienced difficulty. Only one or two students could receive individual help from the teacher as they did their calculations. Since the CAI was introduced, there has been an improvement in the write-up of labs as well as the performance on the first test on measurement and error.

The program is written in BASIC for a 16K TRS-80 but can be easily adapted for use on any microcomputer programmable in BASIC language. Copies of the program listing, sample data, sample execution, and the lab procedure are available from the author for a $5.00 postage and handling fee. If a cassette tape to run on a TRS-80 is desired instead of the listing, send $10.00. Please make the check payable to the author.

KELLEY 9

# A Simple but Effective Demonstration for Illustrating Significant Figure Rules When Making Measurements and Doing Calculations

Arden P. Zipp
SUNY–Cortland, Cortland, NY 13045

Beginning students in chemistry frequently have difficulty with the mathematical aspects of the subject. These include (but are not limited to) recognizing the errors inherent in experimental measurements (*1*) and making proper use of significant figures (*2*). Students can be surprised and confused when different arithmetical operations are performed on experimental data, because the rules change when changing from addition or subtraction to multiplication or division. The following is a simple way to illustrate several aspects of these rules.

## Making Measurements

Take three containers that can be read to different degrees of precision, e.g., an 800-mL beaker (±20 mL) a 250-mL graduated cylinder (±1 mL), and a 10-mL graduated cylinder (±0.02 mL). Fill each about half full with water. Have two (or more) students measure and record the volume in each cylinder independently. Have them describe how they obtained their values, including the number of decimal places each value should have, i.e., how they fixed the level of uncertainty in each measurement. Note how the difference in marking precision influences the uncertainty; that is, the person making the measurement determines to what precision the measurement can be made and, thus, fixes the uncertainty (which is always in the last decimal place of the measurement).

Demonstrate how to calculate the mean value in each cylinder from the measured values and explain that the uncertainty in it would be the absolute difference between the mean and the measured values. Comment on the reasons for making several measurements rather than one or two and demonstrate by having several people measure the volume in one of the cylinders and compute the mean. (The concept of standard deviation may be introduced at this time if desired.)

## Subtraction of Measurements

Pour some water out of the larger cylinder and have two students record the volume of water left, noting that the uncertainty in this reading is the same as that in the original volume reading using this cylinder. By subtracting, determine the volume of water poured out. Show (by using the percentage uncertainties or the maximum-minimum method) that the uncertainty in the final volume doubles. That is, manipulation of measurements always increases the degree of uncertainty in the result.

## Addition of Measurements

Add the measurements of the water in the 250-mL and the 10-mL cylinders, illustrating the limitations of adding uncertainties in different decimal places.

Pour the water in the 10-mL cylinder into the 250-mL cylinder. Record the total, including its uncertainty. Compare the measured value with the calculated one. Ask students which one is "right". Pour the water from the 250-mL cylinder into the 800-mL beaker. Ask students to determine the volume and the uncertainty again. Emphasize the fact that the precision with which the final volume can be established is limited by the uncertainty in reading the level of the water in the 800-mL beaker (20 mL). The more precise values obtained for the volumes in the two graduated cylinders (1 mL for the 250-mL cylinder and 0.02 mL for the 10-mL cylinder) are of little use in fixing the uncertainty of the total. These various examples should establish the rule for addition and subtraction; i.e., the final answer may contain no more decimals than are present in the number with the fewest decimals.

## Possible Extensions

The rules for using significant figures during multiplication or division also may be introduced with this simple demonstration. The rules for division can be illustrated by calculating the ratio of any two of the original volumes along with the uncertainty in this ratio (using either the percentage uncertainties or the maximum-minimum procedure). This calculation should fix the rule in students' minds the rule that the number of places in a quotient (or product) can be no greater than that in the number with the fewest.

Alternatively, the volume of water in the 250-mL cylinder can be calculated from the diameter of the cylinder and the height of the water in it. If the precision of one of these measurements (e.g., the height) is varied while the other is kept constant, the number of significant figures that should be kept in the result can be compared. Finally, the volume determined in this manner (and its uncertainty) can be compared with the volume measured originally along with its uncertainty.

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# Meter Sticks in the Demonstration of Error Measurements

**Robert Suder**
Austin Science Academy at LBJ High School
7309 Lazy Creek Lane
Austin, TX 78724

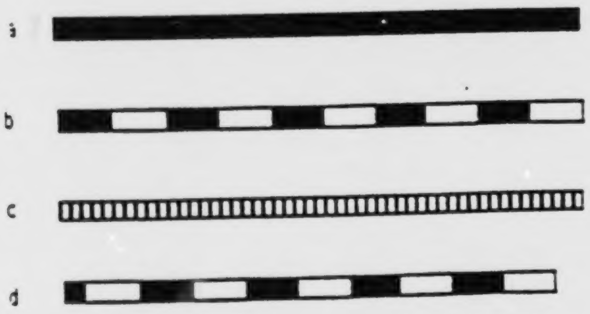
At the beginning of the school year, general chemistry students are taught that the number of significant figures and the error involved in a measurement are dependent on the measuring device. This can be demonstrated in several ways. One method is to have the students measure the mass of an object using three different balances, a triple-beam, a centigram, and an analytical balance. These balances have errors of ±0.1 g, ±0.01 g, and ±0.0001 g, respectively. This exercise not only familiarizes the students with the use of the balances, but also demonstrates that there will always be an error involved in every measurement. The use of a better measuring device will reduce but not eliminate the error. In addition, the better the measuring device, the more significant figures obtained.

However, a more satisfactory method of showing the error involved in measurement is by using the three meter sticks shown in the figure. Meter stick a has all the numbers painted over so that only meters can be read. Meter sticks b and c are painted in such a way as to divide them into tenths (decimeters) and hundredths (centimeters). I prepare the meter sticks by simply making either a 1-cm or a 1-dm mask and then spray with alternating black and white paint.

I begin the demonstration by drawing two lines on the blackboard about 5 cm long and 80 cm apart, and then have the students measure the distance between the lines using the three meter sticks. Meter stick a permits only one significant figure, the tenths of a meter, which is the estimated digit. Then they repeat the measurement using meter stick b. This permits two significant figures, in which case the tenths are exact and the hundredths are estimated. Finally, using meter stick c, the tenths and hundredths are measured exactly and the thousandths are estimated. This exercise clearly shows the students that the number of significant figures obtained in a measurement is only dependent on the measuring device. To reinforce this concept, I draw two lines on the blackboard about 8 cm apart, and I have the students estimate the distance in centimeters between them using meter stick c. This will result in two-significant-figure accuracy. Then I have them convert their result to meters. For example, 8.3 cm = 0.083 m. Next I ask how many significant figures are in the value 0.083 m. Invariably they will answer three. I then point out that the number of significant figures cannot change because the measuring device has not changed. This allows me to explain the two uses of the zero; to locate the decimal place, in which it is not significant, or as a measured value, in which case it is significant.

The meter sticks can also be used to illustrate the difference between random and systematic errors. Again I draw two lines on the blackboard about 70 cm apart. Then I have the students estimate the distance using meter stick b. I write their estimations on the blackboard, compute the average, and then measure the distance using meter stick c, which is assumed to be the correct value. I next show that the average value is very close to the correct value, and also that there are as many estimations above the correct value as below it. This is defined as random error, or error arising from determining the estimated value of a measurement, and it cannot be eliminated. Finally, I use meter stick d, which has the left end cut short, to measure the distance between the same lines. This results in measurements that are consistently too large. I explain this in terms of systematic error, or error caused by a faulty procedure or measuring device. Systematic error can be eliminated by using one of the other meter sticks.

The use of these four modified meter sticks has made it much easier for my students to grasp the concept of errors involved in measurements.



Four meter sticks prepared to show how precision of the measuring device affects significant figures and how random and systematic errors occur.

J. Chem. Educ., 66(5), 1989, p. 43

# More on the Question of Significant Figures

**Howard J. Clase**
Memorial University, St. John's, Nfld., Canada, A1B 3X7

Arden P. Zipp's watery practical demonstration of the rationale behind the significant figure rules for calculations (*1*) reminded me of a dryer method I have used, which has generated favorable feedback from students in an introductory chemistry course. This method introduces a new digit into calculations, the "?", pronounced "unknown". It is used to distinguish conventional zeros, which are merely place markers, from those that are true measured or mathematically exact zeros.

After discussing the difference between the exact numbers of mathematics and the limited precision of measured values I suggest that we indicate any unknown digits with "unknowns" instead of zeros. For example, using a 500-mL graduated beaker to measure a volume of water we might come up with 330 mL to the nearest 10 mL. This would be written as 33? mL to indicate the nonsignificance of the last place.

In calculations the arithmetical rule for dealing with this new digit is the same irrespective of the actual operation: the result of addition to, subtraction from, multiplication by or division by ? is always ?. This point is readily grasped. Apart from this, the normal rules of arithmetic apply. Here are a couple of examples:

**Addition:**
1.340??
0.0008?
0.78523+
Answer: 2.126?? i.e., 2.126

**Mulplication:**
234??
24?×
?????
936??
468??
Answer: 56????? i.e., $5.6 \times 10^6$

Note:. Where a sum involving a ? is clearly greater than 10 I have carried the 10 in the addition.

Since very few calculators have a "?" button, calculations involving the unknown digit have to be done the long way. You should find that this works with any long method of multiplication or division and gives the same result as the application of the significant figure rules. While the method could be developed further with "rounding off" rules etc., I do not think there is much point; I am not proposing it for general use, but as a method for conveying to students with no knowledge of statistics an understanding of what is behind the significant figure rules used with calculators. Students who realize that the rules are not arbitrary should find it easier to remember and apply them. Get your class to try one or two for themselves, and perhaps you, too, will have someone come up to you after the class and say, "Sir! That's the first time I ever understood what significant figures are about."

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KELLEY 12

# Measuring with a Purpose

## Involving Students in the Learning Process

**Patricia A. Metz**
Texas Tech University, Lubbock, TX 79409

**Jeffrey R. Pribyl**
Chemistry and Geology Department, Mankato State University, Mankato, MN 56002

Science relies heavily on observations, and many of those observations are quantitative in nature; therefore, it is important for students to have a working knowledge of measurement. The first class periods of many beginning chemistry courses, both high school and college, deal with this concept. Many teachers and textbooks (*1–5*) take a rule-based, algorithmic approach to the topic. As a result students sometimes develop a poor first impression of chemistry from this boring, rote memorization lesson. We prefer to engage our students in a learning activity that leads them to understand the need for and application of rules in measurement (*6–7*). Such an approach is based upon the constructivist theory of learning (*8*) that states that knowledge is constructed in the mind of the learner, not transferred intact from the instructor. This paper discusses a learning activity we have used effectively with our students to teach measurements and related introductory topics.

### Getting Started

The activity centers on a metal brick or suitable substitute (any solid, rectangular object). As students arrive for class each one is called up to the front of the room, handed a ruler, and asked to measure the longest edge of the metal brick. The type of ruler, English or metric, does not matter as long as an assortment is used and several students use each ruler. In addition to a commercial yardstick and meter stick, use several homemade rulers. (We made three meter sticks and two yardsticks out of wood strips. Each was appropriately labeled "1 m" or "1 yard." One meter stick was divided into 10-cm units, another into 1-cm units, and the third had no divisions. One yardstick was divided into 1-in. units and the other had no divisions.) Record all measurements and the type of ruler used on a sheet of paper. Once the class has assembled, explain what has been happening and write the students' measurements on the board, e.g.,

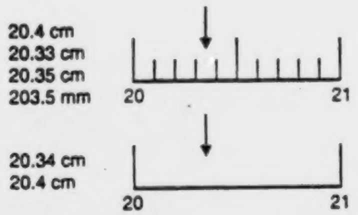
| | | | | |
|---|---|---|---|---|
| 20.4 | 20.34 cm | 20 cm | 2/3 ft | 8 1/16 in. |
| 20.33 cm | 20.4 cm | 1/4 m | 0.25 yd | 8 1/32 in. |
| 20.35 cm | | 23.5 | | 8 |
| 203.5 mm | | 0.2 m | | 8.03 in. |

Ask the students to examine the data and comment. This particular set of data triggered comments about missing units, metric versus English measurements, the number of digits, and range of values. Use the students' observations as the starting point for discussions of numbers versus measurements, the similarity of numbers for metric measurements (203.5 mm, 20.4 cm, 0.2 m) but not English measurements (8 1/16 in., 2/3 ft, 0.25 yd), why the metric and not the English system is used in science, and precision of the ruler.

### Significant Figures

Precision is discussed last and is used to introduce significant figures. Because our concern with significant figures is linked to measured values, we base our teaching of significant figures on actual measurements and not a given set of rules.

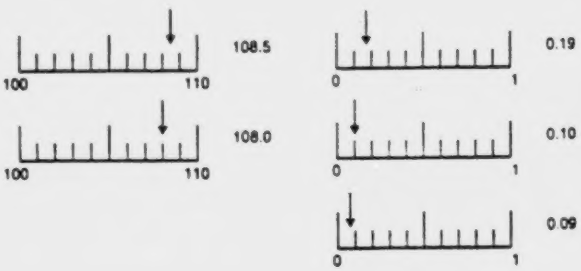
Point out all the measurements made with the same ruler or scale, e.g.,



Discuss (1) whether the measurements are possible with the scale used, (2) how to read a scale properly including one estimated figure, (3) the precision of the scale, and (4) which figures are certain in the number and which are uncertain. To avoid unnecessary confusion with this introductory chemistry topic, we only use scales divided into units of 10 and never those divided into units of 2 or 5.

### When Zeros are Significant

After students understand the concepts of measurement precision and significant figures, discuss when zeros are significant, but do this in the context of a measurement scale. When students have concrete examples of measured values that contain a zero, they are better able to grasp the idea of when zeros are significant (*9*). We use examples such as



A zero to the left of the decimal point or a trailing zero are always problems for students. Many textbooks tell students to write the number in scientific notation (*1–5*). This is a reasonable approach to the problem, but most students at this stage of their learning do not fully understand scientific notation. An alternative is to have students write the number as a fraction. For example 0.10 is written

$^{10}/_{100}$ and has two significant figures. One would not write $^{010}/_{100}$ because the leading zero has no meaning. Likewise $^{1}/_{100}$ is incorrect because it indicated an amount one-tenth the actual size.

### Calculations of Measured Values

The next topic deals with calculations and significant figures. Highlight all the correct metric measurements for the longest edge of the metal brick and ask the students to calculate the average length, e.g.,

| | | | | |
|---|---|---|---|---|
| 20.4 | 20.34 cm | **20 cm** | 2/3 ft | 8 1/16 in. |
| **20.33 cm** | 20.4 cm | 1/4 m | 0.25 yd | 8 1/32 in. |
| **20.35 cm** | | 23.5 | | 8 |
| **203.5 mm** | | 0.2 m | | 8.03 in. |

This exercise can provide an opportunity to discuss a variety of points such as (1) why uncertainty must be taken into account in the calculation, (2) how to deal with more than one uncertain figure in the answer or rounding, (3) what the rule is for significant figures in addition and subtraction problems, (4) how to choose the appropriate ruler (or scale) for a given task, (5) why and how to eliminate data entries that are out of line with the data set, and (6) why it is better to average with an odd number of data values than an even number.

Next provide the class with the dimensions of the metal brick, e.g., 20.33 cm × 5.02 cm × 10.14 cm. Divide the class into three sections and ask each section to calculate the area of the largest, the medium-sized, or the smallest face of the brick. Invariably someone will ask which value is the length, width, and height. Show the students the brick again and allow them to resolve the dilemma themselves. Record the answers on the board and ask students to comment. Again comments will vary. Some points for discussion might include proper units, inconsistent values, and range of significant figures in the answers. This last item is used to introduce significant figures in multiplication and division calculations.

The uncertainty in multiplication is addressed by calculating the area longhand with each uncertain number highlighted (*10*), e.g.,

$$\begin{array}{r} 20.33\text{ cm} \\ \underline{10.14\text{ cm}} \\ 81\ 32 \\ 2\ 03\ 3\phantom{0} \\ \underline{203\ 30\phantom{00}\phantom{\text{ cm}}} \\ 206.14\ 62\text{ cm}^2 \end{array} \longrightarrow 206.1\text{ cm}^2$$

Because the idea of only one uncertain figure per measurement was discussed earlier with the average length problem, students should recognize the correct answer is 206.1 cm². They also should recognize the fact that this process is long and tedious. Hence, the need arises for a simpler means to determine the number of significant figures in a multiplication problem. Now is the time to introduce the rule for determining significant figures in multiplication and division calculations. It is important to explain that the accepted rule does not work every time. You can prove this to yourself by calculating the area of the medium-sized face by longhand.

$$\begin{array}{r} 20.33\text{ cm} \\ \underline{5.02\text{ cm}} \\ 40\ 66 \\ \underline{101\ 65\ 0\phantom{\text{ cm}}} \\ 102.05\ 66\text{ cm}^2 \end{array}$$

Based on uncertain figures in the calculation the area is 102.1 cm²; however, the accepted rule for significant figures tells us to record it as 102 cm².

### Area

Although students have little difficulty calculating the area of a surface, they often do not understand what is meant by area. If you ask them, "What does 206.1 cm² mean?" students will more than likely respond, "The product of the length times the width." Pursue the issue further by asking,

- What is the value of the number, not how it is calculated?"
- What is a $cm^2$?
- What does a $cm^2$ look like? (show a cutout of a square centimeter)
- How many of these squares (show a handful of cutouts) would it take to cover the largest face of this metal brick? (Show this idea by sticking the squares on the face starting in the upper left-hand corner.)

### Scientific Notation

Next have the students calculate the volume of the brick, e.g.,

$$20.33\text{ cm} \times 5.02\text{ cm} \times 10.14\text{ cm} = 1034.854\text{ cm}^3$$

Note this time that there are two uncertain figures to the left of the decimal (1030). This poses a problem. Introduce scientific notation as a means to resolve this uncertainty. The answer now becomes $1.03 \times 10^3$ cm³ and the rule for significant figures in a multiplication problem is followed once again.

Use this time to discuss the meaning of volume just as you did area earlier. Questions for discussion might include

- What does $1.03 \times 10^3$ cm³ mean?
- What is a $cm^3$?
- What does a $cm^3$ look like? (sugar cubes are approximately a $cm^3$)
- How many sugar cubes would it take to build a similar shaped brick out of sugar cubes?

### Density

What metal is the brick? Provide the class with several choices e.g., iron, copper, mercury, gold, nickel, silver, and zinc. Discuss common properties of these metals and eliminate choices where possible, e.g., mercury is a liquid at room temperature, gold and silver are too expensive for instructional devices, and the brick is not the color of copper or gold. Provide the mass in grams of one cubic centimeter of each possible metal and the mass of the brick. Give the mass of the brick in pounds and have students calculate its mass in grams per cm³. This provides the students with an opportunity to do an English-metric conversion. Use this problem to discuss the concept of density and the process of dimensional analysis.

### Summary

The end result of this exercise is that an often boring, confusing, and highly rule-based lecture topic has been turned into a student-centered activity. The students have become active learners instead of passive listeners or spectators. The idea of measurement is now based on concrete examples and the students have constructed their knowledge of the subject. Furthermore, students have had the opportunity to ask and answer questions concerning measurement and have come, it is hoped, to a better understanding of this important basis of scientific work.

## Acknowledgment

The authors would like to thank Claire Baker and Dudley Herron for initiating this instructional strategy.

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J. Chem. Educ. 72(2), 1995, p. 132

Activity (9)

## Significant Figures

Often beginning chemistry students have a hard time understanding significant figures. With calculators showing up to 10 digits, students perpetually report too many significant figures. Presented is a very simple demonstration that can be used in class or lab to show how many significant figures to report when using addition or subtraction.

The demonstration requires a 500-mL beaker with graduations of 50 mL and a 100-mL graduated cylinder with graduations of 1.0 mL. Fill the beaker with about 270 mL water and the cylinder with about 65 mL. Have several students determine the volume of water in each as accurately as possible and write the answers of each on the board. The beaker can be read to within 10 mL and the cylinder to 0.1 mL. Have the class add up the two numbers on the board. A calculator may show the answer to be 337.3 mL. Obviously, this number is being reported more accurately than warranted.

To show why that answer has too many significant figures, pour the water from the cylinder into the beaker. You will have just "added" the two numbers together. Now have the same students determine the new volume of water in the beaker as accurately as possible. The accuracy will only be within 10 mL, not 0.1 mL.

**Kenton B. Abel**
**William M. Hemmerlin**
Pacific Union College
Angwin, CA 94508

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KELLEY 15

# A Simple Laboratory Experiment Using Popcorn To Illustrate Measurement Errors

**Doris R. Kimbrough**[1] **and Robert R. Meglen**
Campus Box 194, P. O. Box 173364, University of Colorado at Denver, Denver, CO 80217

The concepts of accuracy and precision, uncertainty and significant figures are discussed in the first chapter of most general chemistry texts and recently were discussed in an article in *this Journal* (*1*). From their texts, students generally learn a "rule of thumb" method of determine the appropriate number of significant figures (*2*) for the numerical answer to a problem, but most students have lost the reasoning behind this method and focus only on the rule itself. A more rigorous treatment of error analysis generally is not introduced until analytical chemistry or physical chemistry laboratory; however, a large majority of general chemistry students (biology majors, pre-med students) never reach these upper division chemistry courses and seldom see any practical application of significant figures.

The use of significant figures rarely is treated any differently in the laboratory portion of the course. Introductory science students have difficulty linking the lecture concepts of accuracy and precision with the physical measurements they make in the laboratory. Students are familiar with the concept of experimental error because their results often do not match the "expected" or "correct" values dictated by the lab manual or last years' results, but they do not recognize that error is inherent in any measurement.

The following is an experiment used at the University of Colorado at Denver in the first-semester general chemistry laboratory. Popping corn is used to illustrate the scientific method (*3*, *4*) and to illustrate measurement errors. The experiment focuses on the difference between accuracy and precision and demonstrates the necessity for multiple measurements of an experimental variable. It provides the students an opportunity to understand better the concept of significant figures through practical experience, and it helps them to learn some elementary statistics.

## Experimental

The students are provided with a description of the theory behind the experiment including a brief discussion of the nature of measurement errors and definitions of accuracy, precision, random indeterminate, and determinate errors. Each student is directed to weigh (to 0.001 g) 10–15 generic brand and a similar number of gourmet brand popcorn kernels and to identify each so its weight after popping can be compared with that before popping. Each kernel is popped by heating it in a 125-mL Erlenmeyer flask, using a pair of tongs to hold the flask over a Bunsen burner flame. The popped kernel is dumped quickly from the flask, reweighed, and the process is repeated until at least 10 of the kernels have been popped successfully. (Note that for our purposes, "popped" means any kernel that has exploded and released its water contents as steam, regardless of its appearance.)

Each student prepares a table comparing individual masses and their deviations to the average masses for each brand, popped and unpopped. Each mass deviates slightly from the calculated average, and the students compute that deviation (by subtracting the individual mass from the average) as well as the square of the deviation for each tabulated value. They calculate the standard deviation ($\sigma_n$ and $\sigma_{n-1}$) for each set of 10 values. The students use the computed averages and standard deviations to draw conclusions regarding the differences between popped and unpopped average masses, between generic and gourmet brand average masses, mass losses on popping, and any standard deviation differences between the brands. (Advanced students are encouraged to test the statistical significance [t-test and F-test] between their generic and gourmet averages and the significance of their results relative to the pooled results of the whole class.)

## Materials

- Two brands of unpopped popcorn (generic and gourmet brands)
- 100–125 mL Erlenmeyer flask
- Bunsen burner
- burner striker
- burner wire gauze
- chemical tongs

- ***Caution***: Normal laboratory safety procedures should be followed including **wearing safety goggles** and **cautions regarding the use of open flames in the laboratory.** In addition, the students are instructed NOT to eat the popcorn at any time during or after the experiment.

## Results

A typical student data sheet, containing only the results for the generic brand popcorn, is shown in Table 1. The students complete a similar table for the gourmet brand popcorn. While we do not require general chemistry students to perform the statistical tests for significance of differences, it is interesting to note that the typical student result shows that the average popped and unpopped masses are significantly different for both popcorn brands. However, the large variances for only 10 observations does not permit one to conclude that the differences between the brands is statistically significant. The importance of making many measurements to improve the strength of inferences can be made by examining the pooled results from an entire class of 27 students (Table 2). These results ($N = 270$) show that the popped and unpopped masses differ for both brands and are statistically significant (99.9%) and that the gourmet brand kernels have statistically significant (99.9%) smaller masses than the generic brand (both popped and unpopped masses). This result may be presented to the students in a follow-up to the experiment when results are discussed and interpreted.

## Discussion

Most general chemistry texts provide a section on measurement errors that includes formulas for computing the standard deviation. In addition, most student calculators contain the statistical functions necessary for computing means and standard deviations. However, in this experiment we provide our students with sample calculations

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[1] Author to whom correspondence should be addressed.

**Table 1. Student Data Sheet for Unpopped and Popped Generic Brand Popcorn**

| | Unpopped Mass (g) | Dev. from Ave. (g) | Squared Dev. $(g)^2$ | Pop-ped Mass (g) | Dev. from Ave. (g) | Squared Dev. (g)2 | Loss on Popping (g) |
|---|---|---|---|---|---|---|---|
| | 0.122 | 0.0308 | 0.00094864 | 0.113 | 0.0243 | 0.00059049 | 0.009 |
| | 0.186 | 0.0332 | 0.00110224 | 0.168 | 0.0307 | 0.00094249 | 0.018 |
| | 0.139 | 0.0138 | 0.00019044 | 0.124 | 0.0133 | 0.00017689 | 0.015 |
| | 0.142 | 0.0108 | 0.00011664 | 0.117 | 0.0203 | 0.00041209 | 0.025 |
| | 0.181 | 0.0282 | 0.00079524 | 0.163 | 0.0257 | 0.00066049 | 0.018 |
| | 0.089 | 0.0638 | 0.00407044 | 0.081 | 0.0563 | 0.00316969 | 0.008 |
| | 0.182 | 0.0292 | 0.00085264 | 0.166 | 0.0287 | 0.00082369 | 0.016 |
| | 0.199 | 0.0462 | 0.00213444 | 0.183 | 0.0457 | 0.00208849 | 0.016 |
| | 0.147 | 0.0058 | 0.00003364 | 0.132 | 0.0053 | 0.00002809 | 0.015 |
| | 0.141 | 0.0118 | 0.00013924 | 0.126 | 0.0113 | 0.00012769 | 0.015 |
| Average | 0.1528 | | 0.00103836 | 0.1373 | | 0.00090201 | 0.0155 |
| Standard Deviation ($n = 10$) | | | 0.032 | | 0.030 | | |
| Exptl. Std. Dev., (df = $n - 1 = 9$) | | | 0.034 | | 0.032 | | |

**Table 2. Pooled Results from 27 Student Experiments Statistical Comparisons Among Means (Total Number of Observations 270)**

| | Mean in (g) | Std. Dev. (g) | Std. Error (g) | Difference Mean.(g) | Std.Dev. in (g) | t-Value df = 269 | 2-tail[a] Probability |
|---|---|---|---|---|---|---|---|
| Comparison of popped and unpopped means for both brands | | | | | | | |
| Gourmet unpop | 0.1358 | 0.018 | 0.001 | 0.0157 | .010 | 26.43 | 0.000 |
| Gourmet popped | 0.1201 | 0.019 | 0.001 | | | | |
| Generic unpop | 0.1454 | 0.032 | 0.002 | 0.0164 | .009 | 30.20 | 0.000 |
| Generic popped | 0.1290 | 0.030 | 0.002 | | | | |
| Comparison of between brands (popped and unpopped) | | | | | | | |
| Gourmet unpop | 0.1358 | 0.018 | 0.001 | −0.0096 | .036 | −4.43 | 0.000 |
| Generic unpop | 0.1454 | 0.032 | 0.002 | | | | |
| Gourmet popped | 0.1201 | 0.019 | 0.001 | −0.0089 | 0.35 | −4.21 | 0.000 |
| Generic popped | 0.1290 | 0.030 | 0.002 | | | | |

[a] Probability that a difference of this magnitude could be due to sheer chance.

and ask them to perform a more laborious detailed computation for at least one data set to focus their attention on how individual deviations contribute to the concept of the standard deviation. The difference between standard deviation, $\sigma_n$, and the experimental or sample standard deviation, $\sigma_{n-1}$, is discussed in the handout with regard to the fact that only 10 data points are taken in this experiment.

In addition, for lab experiments coordinated with computer training, students can enter their data into a spreadsheet program to prepare the tables, perform the calculations, and pool the results with other students in the laboratory. The graphical functions that accompany most spreadsheet programs will permit each student to prepare a plot of the frequency distributions associated with multiple measurements. The data from the entire laboratory section can be compiled, and the students can compare the variance obtained from 10 measurements to the much smaller variance obtained from 250 to 300 measurements.

## Conclusions

We believe that this experiment is a versatile exercise, because it can be performed at several different levels of experimental and computational sophistication. In addition, the experiment provides a method to introduce the concept of investigator collaboration by allowing several students to pool their results (particularly using the spreadsheet option outlined above) and to observe how experimental confidence levels may be improved through replication and increased numbers of observations. This also is a convenient introductory experiment from a practical standpoint. It requires that the students use only a balance and a Bunsen burner. They gain experience in recording data in tabular form along with an early introduction to experimental uncertainty and error analysis. After performing this experiment, the students make an inference from a measured quantity (kernel weight) and an observed phenomenon (kernel popping). Students also develop some understanding of the application of science to check the validity of commercial claims.

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## Error, Precision, and Uncertainty

**Charles J. Guare**
AOP Office
Union College
Schenectady, NY 12308

This paper was prepared in response to requests from several chemistry instructors for information following my letter, "Duplicating the Confusion," in *Chemical & Engineering News*, January 22, 1990. Its objective is to provide answers to questions that frequently arise about experimental error, precision, and uncertainty in introductory chemistry courses, and to keep the answers consistent with accepted definitions.

In the literature and textbooks the arithmetic of science and engineering is rarely presented as a neat, self-consistent package. One may read that precision is a measure of error (*1, 2*) or that error and uncertainty are the same thing (*3*). Authors may state that significant digits are related to error but that a number with more significant digits to the right of the decimal point is a more precise number (not necessarily a more correct number), thereby showing that significant digits are related to precision and not to error. The student may be told that "error propagation" is conducted according to one rule for addition and subtraction, a different rule for multiplication and division, still another for logarithms, and more rules for other functions. Strangely, a student may find that the definitions and rules for doing the arithmetic needed to handle the experimental data generated in a laboratory course may not be the same in the laboratory text and in the recitation text.

If students in introductory engineering and science courses are confused about the arithmetic procedures for handling their data and results, there is adequate reason.

### Definitions

Following are the definitions on which this paper is based.

**Accuracy:** a measure of the closeness of an experimental value to the true value (*4*, p 612).

**Error:** a measure of the departure of an experimental value from the true value (*5, 6*, pp 15–16).

**Precision:** a measure of the reproducibility of a set of results from replicate runs. "It [precision] does not matter how close the average of these runs is to the true value; thus, precision and accuracy are defined independently of each other" (*4*, p 612).

**Significant digits:** in a number, all the digits that are certain plus the first uncertain digit. All digits to the right of the first uncertain digit are dropped; e.g., 12.0 ±1.0 is no more informative than 12 ±1 (*4*, p 609; *6*, p 22).

**Uncertain digit:** any digit that can vary by at least plus or minus 1 (*4*, p 609; *6*, p 22; *7*, p 7).

**Uncertainty:** the range a data value may have because of the need to estimate (interpolate) the last digit being read from an instrument scale; the range a calculated result may have because of the uncertainty in the data or results from which it is calculated. Thus 7.82 ±0.02 has an uncertainty of 2 in the hundredths position. Hundredths is the first uncertain digit.

We may distinguish among error, precision, and uncertainty as shown in Figure 1. The abscissa values A and D represent two individual measurements of some quantity, B is the mean of a large number of measurements of the same quantity, and C is the true value of the quantity. The uncertainty in A and D is shown by the band about each, assigned by the experimenter at the time of reading the measured value. A − C and C − D are the errors for A and D. The precision for the two measurements, taken as the average absolute deviation from the mean of A and D, is (A − D)/2. B − C is the bias. B will be unknown to any experimenter who has made only a few measurements and C may be unknown to everyone.

### Students' Questions

#### *Are Uncertainty and Precision the Same?*

No. Uncertainty in data is estimated by the experimenter at the time of taking a reading and is influenced by, among other things, the closeness and coarseness of the graduation marks on the instrument scale, the visual acuity of the observer, and the fluctuation of the instrument pointer posi-

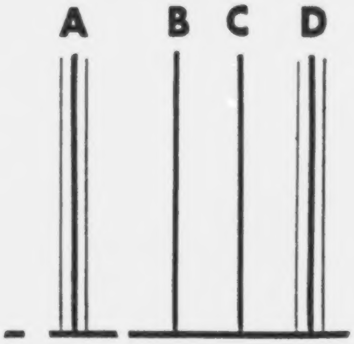

Figure 1. Distinction among error, precision, and uncertainty. The abscissa values are: *A* and *D* = two individual measured values and their bands of uncertainty; *B* = the mean of a large number of measurements; *C* = the true value. The errors in the two measured values are given by the distances *A* − *C* and *C* − *D*. The precision of the two measurements, using the average absolute deviation from the mean, is 0.5 (*D* minus *A*). *B* − *C* is the bias.

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tion because of mechanical or electronic instability in the instrument.

Precision, on the other hand, is represented by a calculated index such as the average absolute deviation from the mean or by the standard deviation for a series of measurements. Nevertheless, uncertainty hints at precision. A number like 27.83 ±0.01, with four significant digits and uncertain at hundredths, is not as precisely expressed as the same number read from a better instrument and expressed as 27.834 ± 0.001, with five significant digits and uncertain at thousandths. This is so whether 27.834 is the true value or not. Significant digits are controlled by uncertainty and are related to precision, not to error.

The uncertainty, ±0.01, does not imply that a duplicate measurement is expected to fall within the range 27.82–27.84 nor that 27.83 lies within 0.01 units of the true value. Uncertainty is not a direct estimate of precision or error. It is an estimate of how well the number could be read when it was read.

### *How Does Uncertainty Differ from Error?*

Consider the case of a student using a 100-mL graduated cylinder that has a manufacturer's tolerance of 3%.

The student fills the cylinder to about the 90-mL mark and estimates the meniscus to be at 90.5 ±0.5 mL. This ±0.5 mL is often recorded as the estimated error in the reading, and, if this volume is added to another, say 40.5 ±0.5 mL, assuming no change in volume on mixing, the estimated maximum possible error in the total volume of 131 mL is declared to be 0.5 + 0.5 or 1 mL.

This approach is obviously incorrect. There is no reason to assume that, because the meniscus position can be read to ±0.5 mL, then the graduation marks on the cylinder must also lie within ±0.5 mL of the true position.

The student is estimating that, under the conditions prevailing at the time of the measurement, the meniscus was between the 90- and 91-mL marks regardless of how correct those marks are. The student is neither estimating how well he or she can duplicate pouring 90 mL of liquid (experimental precision) nor how far the volume is from being correct (experimental error).

The maximum possible error in the readings comes from the manufacturer's data. If the tolerance on the glassware is 3%, the maximum possible errors are 0.03 × 90.5 = 2.7 mL, 0.03 × 40.5 = 1.2 mL, and, for the total, 2.7 + 1.2 = 3.9 mL.

There is another reason why the band of uncertainty about an individual value cannot be considered error. If we make two measurements of some quantity, experience shows that the two measurements might well not be identical, and there will be an uncertainty associated with each. If the first one is 105 with an uncertainty of ±1 and the uncertainty is taken to be error, we conclude that 105 lies within one unit of being true. If the second one is 95 ±1 and the ±1 is again considered error, we are faced with the dilemma of claiming both 95 and 105 are within one unit of the same true value. We may reasonably say that each number, true or not, lies within one unit of the values read from the instrument, but we may not reasonably say that two numbers that differ by 10 both lie within one unit of the same true value.

This argument agrees with the definitions of accuracy, error, and uncertainty in definitions above and with Barford (*6*, p 16) who writes:

$$\text{error} = x - X$$

where $x$ = the measured value
$X$ = the true value

but it conflicts with J. R. Taylor (*3*, p 15) who says:

$$\text{measured value of } x = x_{\text{best}} \pm dx$$

where

$x_{\text{best}}$ = best estimate for $x$,
$dx$ = uncertainty or error in the measurement

confusing uncertainty with error and leading to the dilemma above with $x_{\text{best}}$ being 95 or 105 and $dx = 1$.

Confusion of error with uncertainty is frequently present in texts, and the student is taught "rules for propagation of error" when what is being propagated is uncertainties that have nothing to do with error.

### *What Is Needed To Be Able To Assess Error?*

Barford (*6*), J. R. Taylor (*3*), J. K. Taylor (*8*), and Marion and Davidson (*9*) all agree that a legitimate statement about error can be made only after any combination of experimenter–equipment–procedure has been thoroughly checked out, comparisons with standards have been made, and a large number of measurements have been completed. Even then, some authors contend it is never possible to know the true value of a measured quantity. That is, if a large number of measurements have produced a well-defined distribution curve with a good estimate of the mean, taking the mean to be the true value still involves an assumption.

J. K. Taylor (*8*, p 7) says, "In a stable measurement process, a large number of individual values will tend to converge toward a limiting mean, which may or may not be the true value." Marion and Davidson (*9*, p 18) say, "When we measure some physical quantity, we do not know (nor can we know) the true value of the quantity. Therefore, we can never know the error in the result."

This last seems overly severe. If several experimenters using different equipment and different procedures carefully measure a quantity numerous times to define the data distribution curve in each case, and if the distribution curves all have the same mean, we probably do have the true value. This may not happen very often, but we may certainly be adequately accurate for practical purposes as shown by the economic viability of the chemical industry and the routine dispensing of desired doses of numerous medications. Nevertheless, getting to a position in which one can provide a legitimate error estimate takes much effort and time. That is why we have referee laboratories and why universal constants change over the years.

J. K. Taylor (*8*, Chapters 9 and 10) provides a quality control expert's view of the extensive work necessary to assess errors. His discussion is strongly supported by Rubinson (*10*, Chapter 4) who uses the results of two chemical analyses to show the kinds of difficulties that can arise and produce incorrect data. This material clearly confirms that an error estimate is not something the experimenter pops up with each time he or she takes a reading, and our students should not be misled into thinking they are estimating error every time they assign an uncertainty.

### *Why Not Eliminate Error by Calibrating?*

Calibration is a big step in the right direction, but it does not guarantee identification of the true value for any point on a calibration curve, and it is highly unlikely that all points on a calibration curve represent true values. J. K. Taylor (*8*, p 103, p 106) says, "Ideally, the calibration process is undertaken to eliminate deviations in the accuracy of measurements or instruments. However, this cannot be glibly assumed," and, "Thus, biased measurement data can result when using unbiased methodology because of calibration bias."

In a manner of speaking, the manufacturer's information used to estimate the maximum possible error in the graduated cylinder example above provides some calibration. The manufacturer has done extensive quality control work and knows that his or her graduated cylinders will measure a volume that is within 3% of being correct. We can think of a calibration curve, really a calibration "band", that has a width of ±3% and relates the actual readings to the range of "true" values possible. Much instrumentation will do better than the 3% figure, but it is still unlikely that calibration will produce exact corrections to each scale value. The "calibration curve" always turns out to be a "calibration band" (*8*, Chapter 10).

To illustrate, take a case in which a point on an instrument scale is being calibrated against a standard that has a value of 100. If the experimenter makes numerous measurements of the standard, his or her readings will cover a range of values. Assume they are normally distributed with no bias present.

If we plot the experimental data in three dimensions such that the $x$ axis represents the standard values, the $y$-axis represents the values read from the calibration experiment, and the $z$ axis represents the relative number of times each experimental value was observed above the value of 100 on the $x$ axis, we get a little normal distribution curve in the $y$–$z$ plane. If there is no bias, the mean on the $y$ axis is 100, and the standard deviation has some value, $s$. In practice, this distribution curve would exist but would probably be unknown because few people do all the work necessary to define it.

If we have not defined this distribution curve but we proceed to make a calibration measurement, what is the probability that the measurement will fall within the range of the mean $\pm 1s$? The probability is about 0.68 because about 68% of all data in a normal distribution curve fall within that range (*11*, p 382–383). If we calibrate at five points, the probability that all five will lie within one standard deviation of the true value is 0.68 raised to the fifth power, or about 15%. It is very difficult to eliminate all error by calibration even taking as "correct" anything within a calibration band as wide as $\pm 1s$.

### *Why Does Averaging Improve Accuracy?*

Averaging always improves precision; it may or may not improve accuracy.

Previous discussion shows it is difficult to get the true value in experimental measurements, so it is probable that experimental data and results have a bias of some magnitude. In these cases, the mean of even a well-defined distribution curve is not the true value. This is the reason that precision, as measured by average absolution deviation from the mean or by standard deviation, is not generally a measure of error. These indexes of precision measure the deviation of the replicated data from the mean of that data, not necessarily from the true value.

Let us start out with a distribution curve that results from a large number of *individual* measurements and has a standard deviation of $s$. Suppose we now start making measurements by running *quadruplicates* and averaging the four. It turns out an average of four comes from a new distribution curve that has the same mean as the original, but its standard deviation, $s(4)$, is only half the value of $s$. $s(4)$ is called the standard deviation of the mean. In general, $s(n)$ is $s/n^{1/2}$ ($s(n) = s/n^{1/2}$) (*11*, p 39).

Because this act of averaging has created a value taken from a new distribution curve of smaller standard deviation, the new curve represents a more precise distribution that is contracted about the mean of the old curve. But if the mean is not the true value because of a bias, an average of four is not more likely to be the true value; it is just more likely to be the biased mean. The result is an increase in precision but not in accuracy.

This conclusion depends upon how large the bias is. If it is very small relative to the standard deviation, initial improvement in precision will improve the probability of getting a correct measurement; but if precision continues to improve, the chance that a measurement will hit the true value always decreases. If the bias is as large as one standard deviation, *any* decrease in the standard deviation immediately reduces the probability that a measurement will produce the true value. This is shown in Figure 2, wherein the upper curve represents the frequency distribution of $n$ individual measurements and the lower curve represents the more precise distribution of $n/4$ averages of four measurements. The center vertical line is the mean of either distribution, and the right vertical line is the true value. Note the reduced chance of getting the true value in the more precise case. The same reasoning holds for better precision achieved in other ways, such as by more precise equipment but still with a biased procedure or calibration.

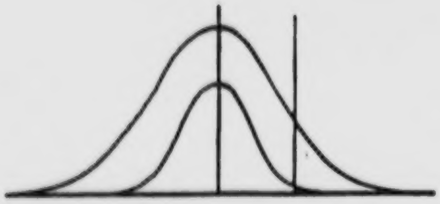

Figure 2. Effects of averaging on precision and accuracy. The upper curve represents the frequency distribution of $n$ measured values of some quantity. The lower, more precise curve represents the frequency distribution of $n/4$ averages of quadruplicates. The center vertical line is the mean of either distribution. The true value is the right vertical line. Note the low chance of getting the true value with a measurement from the more precise case.

The belief that averaging always improves accuracy or that better precision means better accuracy clearly is not correct.

### *Do I Have To Learn a New Rule for Error Propagation for Each Arithmetic Operation?*

In introductory laboratory courses, the student usually makes only two or three measurements, often uses uncalibrated equipment and unfamiliar procedures, and has no idea what the true value is. Under these conditions, it is not possible to estimate error. You are estimating and propagating uncertainty, not error.

You do not have to learn a separate rule for propagating uncertainty for each arithmetic operation. There is a simple, straightforward concept for handling uncertainties and significant digits in calculations. It eliminates the need to learn a variety of rules. It consists of taking the numbers to mean what they say and calculating the maximum, best estimate, and the minimum values possible. The uncertainty and significant digits in the answer then fall out naturally. Elements of the procedure may be found in Marion and Davidson (*9*, p 23) and in Petrucci (*7*, p 9).

*Example 1.* What is the sum of $17.2 \pm 0.2$ and $12.5 \pm 0.1$?

MAXIMUM SUM = 17.4 + 12.6 = 30.0
BEST ESTIMATE SUM = 17.2 + 12.5 = 29.7
MINIMUM SUM = 17.0 + 12.4 = 29.4
UNCERTAINTY IN SUM = (30.0 − 29.4)/2 = 0.3
SUM = 29.7 ± 0.3

*Example 2.* What is the difference between the two numbers of Example 1?

MAXIMUM DIFFERENCE = 17.4 − 12.4 = 5.0
BEST ESTIMATE DIFFERENCE = 17.2 − 12.5 = 4.7
MINIMUM DIFFERENCE = 17.0 − 12.6 = 4.4
UNCERTAINTY IN DIFFERENCE = (5.0 − 4.4)/2 = 0.3
DIFFERENCE = 4.7 ± 0.3

*Example 3.* If $A = 1.19 \pm 0.01$ and $B = 0.286 \pm 0.002$, what is their product? (For multiplication and division, keep the answer one digit longer than the longest factor.)

MAXIMUM PRODUCT = 1.20 × 0.288 = 0.3456
BEST ESTIMATE PRODUCT = 1.19 × 0.286 = 0.3403
MINIMUM PRODUCT = 1.18 × 0.284 = 0.3351
UNCERTAINTY IN PRODUCT = (0.3456 − 0.3351)/2 = 0.00525
PRODUCT = 0.340 ± 0.005

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*Example 4.* What is the quotient of *A*/*B* from Example 3?
MAXIMUM QUOTIENT = 1.20/0.284 = 4.225
BEST ESTIMATE QUOTIENT = 1.19/0.286 = 4.160
MINIMUM QUOTIENT = 1.18/0.288 = 4.097
UNCERTAINTY IN QUOTIENT = (4.225 − 4.097)/2 = 0.064
QUOTIENT = 4.16 ± 0.06

*Example 5.* What is the log of 86 ± 6?
MAXIMUM LOG = log 92 = 1.963
BEST ESTIMATE LOG = log 86 = 1.934
MINIMUM LOG = log 80 = 1.903
UNCERTAINTY IN LOG = (1.963 − 1.903)/2 = 0.030
LOG = 1.93 ± 0.03

*Example 6.* What is the sine of 30 ± 2 degrees?
MAXIMUM SINE = sin 32 = 0.5299
BEST ESTIMATE SINE = sin 30 = 0.5000
MINIMUM SINE = sin 28 = 0.4694
UNCERTAINTY IN SINE = (0.5299 − 0.4694)/2 = 0.03025
SINE = 0.50 ± 0.03

This procedure works for all cases above and can be extended to numbers raised to a power and others. Separate rules for each case are not needed.

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# Teaching Significant Figures Using a Learning Cycle

**E. Park Guymon, Helen J. James,[1] and Spencer L. Seager**
Weber State College, Ogden, UT 84408

"Whatever became of significant figures?"[2] How often do instructors echo this comment as they grade problem sets or lab reports? Can we teach the use of significant figures in a way that will be retained better by our students?

The rules for using significant figures are usually found in the first chapter (or possibly the appendix) of most textbooks and seem to be forgotten quickly by everyone as soon as their discussion in class is finished. The importance of correctly recording measurements is often emphasized in class, but few students seem to recognize that this idea should be applied to data collected in the laboratory. Another frustration occurs because students misinterpret the rules, possibly because the rules are not clearly stated in terms the students understand. This problem is indicated by recent articles that are concerned with the wording used to state the rules governing the significance of zeros in a value.[3,4]

We have developed an exercise called "R and R" (rectangles and rulers) which helps our students establish the rules for themselves. This exercise involves the students in making measurements which helps them relate the use of significant figures to laboratory experiences. We have used R and R in both classroom and laboratory settings depending upon the course being taught.

R and R is written as a learning cycle, a type of activity developed to help students' reasoning and to give them concrete experiences with a new concept.[5] A learning cycle consists of three phases: exploration, invention, and application. During exploration students are encouraged to learn through their own concrete experiences. In the second phase, students are asked to invent part or all of a concept for themselves. This procedure gives students confidence as they gain familiarity with the invented concept. During application the students are required to use the concept in a situation which gives them more understanding. Details of our experiences with the R and R learning cycle are given below.

## Exploration

The students work in pairs which encourages them to discuss results and prod each other to achieve better results. Each team receives a packet of material containing four different colored rectangles and a ruler calibrated in centimeters. We made the rectangles and rulers from plastic index cards. They are sturdy and come in various colors. We used a paper cutter to make the rectangles of a given color as nearly as possible identical in size to all others of that color. The rectangles had the following dimensions: 12.0 × 10.5 cm, 20.0 × 2.5 cm, 13.5 × 0.7 cm, and 3.0 × 2.5 cm. The teams are asked to determine the length, width, perimeter, and area of each rectangle. After completing this task the students are required to repeat the measurements, but with a ruler calibrated in tenths of a centimeter. The results for a team are shown in Table 1. During this exploration many students show lots of concern about estimating values with the rulers that they are using. But few show the same concern whe they use the measured values in calculations. Also, noti that the data in Table 1 indicate that the team estimat readings to tenths of a centimeter, except when the mea-sured value was perceived to be a whole number (the lengt of the black rectangle was recorded as 12 instead of 12.0) When these rectangles are cut, it is important to cut on carefully enough to allow for this type of student result.

Table 1. Typical Student Data

| Rectangle | Length (cm) | Width (cm) | Perimeter (cm) | Area (cm²) |
|---|---|---|---|---|
| Ruler Calibrated to a Centimeter | | | | |
| Black | 12 | 10.5 | 45 | 126 |
| Red | 20.4 | 2.6 | 46 | 53.04 |
| Green | 3.2 | 2.6 | 11.6 | 8.32 |
| Orange | 0.7 | 13.4 | 28.2 | 9.38 |
| Ruler Calibrated to Tenths of a Centimeter | | | | |
| Black | 12 | 10.4 | 44.8 | 124.8 |
| Red | 20.2 | 2.42 | 45.24 | 48.884 |
| Green | 3.18 | 2.55 | 11.46 | 8.109 |
| Orange | 0.68 | 13.22 | 27.8 | 8.9896 |

## Invention

A primary goal of the invention phase is to involve th students and instructor in a discussion that encourages th students to be active learners. We begin this phase by havin each team list its results on a blackboard. Table 2 sho some typical results for the black rectangle. Usually, discu sions (and sometimes arguments) begin among the studen as soon as the first results are listed. We try to center th inital discussion around the question, "Are the record measurements consistent?" Within a few minutes the st dents agree that the length of the black rectangle should b recorded as 12.0 cm or 12.00 cm depending upon the rul used. They begin to recognize that for an experimental me surement the last recorded digit is an estimate that wi include a reading error.

Next, we lead the discussion to consider whether the c culated perimeter and area values are consistent with th correctly recorded lengths. Students often consider resu

Table 2. Typical Data for the Black Rectangle

| Team # | Length (cm) | Width (cm) | Perimeter (cm) | Area (cm²) |
|---|---|---|---|---|
| Ruler Calibrated to a Centimeter | | | | |
| 1 | 12 | 10.5 | 45 | 126 |
| 2 | 12.0 | 10.4 | 44.8 | 124.8 |
| 3 | 12 | 10.6 | 45.2 | 27.2 |
| 4 | 12 | 10.5 | 45.0 | 26.0 |
| Ruler Calibrated to Tenths of a Centimeter | | | | |
| 1 | 12 | 10.4 | 44.8 | 124.8 |
| 2 | 12.00 | 10.52 | 45.04 | 126.24 |
| 3 | 12.0 | 10.5 | 45 | 126 |
| 4 | 12.0 | 10.48 | 44.96 | 125.76 |

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[1] Author to whom inquiries should be directed.
[2] Anderlik, B. *J. Chem. Educ.* 1980, *57*, 591.
[3] Treptow, R. S. *J. Chem. Educ.* 1980, *57*, 646.
[4] Ward, C. R. *J. Chem. Educ.* 1981, *58*, 616.
[5] Karplus, R. "Science Curriculum Improvement Study"; University of California: Berkeley, CA, 1974.

such as those of team number two to be correct. Two exercises usually enlighten them. First, we ask them to determine the perimeter by using the length measured with the first ruler and the width measured with the second. For Team 2 this would be

12.0 cm
12.0 cm
10.52 cm
10.52 cm
45.04 cm

Almost without exception the students agree on a value of 45.0 cm as the correct one. They explain that since only the last digit can be an estimate, the 4 must be dropped or the last two digits will both contain estimates. The students are asked to use these ideas and write a rule for the use of significant figures in addition and/or subtraction operations. In the second exercise we ask the students to calculate areas using a constant length, but a width that has values of plus or minus 0.1 cm from the recorded value. Again, Team 2 would find

Recorded width + 0.1: $12.0\ \text{cm} \times 10.5\ \text{cm} = 126.0\ \text{cm}^2$
Recorded values: $12.0\ \text{cm} \times 10.4\ \text{cm} = 124.8\ \text{cm}^2$
Recorded width − 0.1: $12.0\ \text{cm} \times 10.3\ \text{cm} = 123.6\ \text{cm}^2$

The students see that the results vary in the last two digits. They conclude that since only the last digit can contain any estimate, the results must be rounded, and the correct value should be written as 125 cm². After doing several examples the students begin counting significant figures correctly and actually derive their own rules for multiplication and/or division. In order to clarify the zero problem we ask them to record the length and width in meters and to calculate the area:

$$0.120\ \text{m} \times 0.104\ \text{m} = 0.01248\ \text{m}^2$$

By comparison to the earlier result (124.8 cm²) which was rounded to 3 significant figures, students see that the zero to the right of the decimal in the answer cannot be significant, and, in fact, the result must be rounded to 0.0125 m². These concrete experiences help them recognize the usefulness of the rules and also help them state the rules in their own words.

## Application

The application phase varies depending upon the setting in which we use R and R. In a classroom, students are asked to calculate the volume of a single rectangle. Since it is difficult to measure the thickness of a single rectangle, the students form a stack and determine the average thickness. This approach brings up the relationship between significant figures and counting numbers. In a laboratory setting, the students must determine the readability limits of such equipment as graduated cylinders and burets. We also ask them to decide on the maximum number of significant figures they can obtain for measurements made with these devices.

## Comparison of R and R versus Traditional Approach

During the 1984–85 academic year tests were given to 37 freshmen chemistry students at the beginning of the quarter before they did the R and R activity as a 3-hour laboratory experiment, and at the end of the quarter. These students received no other formal instruction dealing with significant figures. The same end-of-quarter test was given to 97 students who received significant figure instruction in a traditional lecture setting. Circumstances prevented us from giving this group the pre-test before they received significant figure instruction in class. Two test questions dealt with significant figures. One question was a measurement task that required the students to record a measured quantity using the correct number of significant figures. The second question required students to do a calculation and express the result using the correct number of significant figures. The questions were worked out on the test paper and were graded on a 0–3 basis as follows: 0 = no attempt made to solve problem, 1 = question done incorrectly, 2 = correct number of significant figures used but incorrect results obtained, 3 = correct number of significant figures and correct result obtained. The results of the test are given in Table 3.

**Table 3. Pre- and Post-Test Results**

| | Measurement Task | | Calculation Task | |
|---|---|---|---|---|
| Score | Pre-test | Post-test | Pre-test | Post-test |
| R and R Students | | | | |
| 0 | 2 (5.4%) | 1 (2.7%) | 0 (0.0%) | 0 (0.0%) |
| 1 | 16 (43.2%) | 2 (5.4%) | 32 (86.5%) | 24 (64.9%) |
| 2 | 2 (5.4%) | 2 (5.4%) | 3 (8.1%) | 1 (2.7%) |
| 3 | 17 (46.0%) | 32 (86.5%) | 2 (5.4%) | 12 (32.4%) |
| Traditional Students | | | | |
| 0 | 9 (9.7%) | 3 (3.2%) | 7 (7.5%) | 1 (1.1%) |
| 1 | 11 (11.8%) | 16 (17.2%) | 53 (57.0%) | 53 (57.0%) |
| 2 | 4 (4.3%) | 1 (1.1%) | 6 (6.5%) | 3 (3.2%) |
| 3 | 69 (74.2%) | 73 (78.5%) | 27 (29.0%) | 36 (38.7%) |

Both groups handled the measurement task quite well in the post-test. The R and R group did a little better with 91.9% scoring 2 or 3 compared to 79.6% of the traditional students. Neither group did as well on the calculation task, but the traditional students did a little better than the R and R group. Of the traditional students, 41.9% scored 2 or 3, compared to 35.1% of the R and R group.

## Conclusions

The correct use of significant figures can be taught, but we prefer to have students establish the rules rather than memorize them. In our experience, students who do this are more willing to accept the responsibility for using them correctly. In addition, the gentle reminder "remember R and R" is often all that is needed to answer student questions about significant figures. The data collected in the pre- and post-tests indicate that R and R is at least as effective as the traditional approach to teaching significant figures. Try R and R for yourself, or develop your own concrete experiences that allow students to discover significant figures for themselves. You will like the results.

A sample of the materials we use can be obtained for $1.50. Send requests and make checks payable to the Chemistry Department, Weber State College.

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## Significant Figures: A Classroom Demonstration

Submitted by:
**H. Graden Kirksey**
Memphis State University
Memphis, TN 38152

Checked by:
**Paul Krause**
University of Central Arkansas
Conway, AR 72032

Information about a measured property of matter is communicated by the magnitude of the numerical measurement, the unit for the physical quantity employed to record the measured property, and the number of significant figures recorded in the numerical measurement. Students easily comprehend the significance of the first of these, often omit or neglect to record the second as a part of their measurement, and, along with some textbook authors, either carelessly regard or ignorantly disregard the third. The purpose of this classroom demonstration is to show students the function and importance of significant figures in a measurement.

### Materials Needed

The items needed to perform this demonstration are

- Two uncalibrated 1.000-m long sticks
- Two 1.000-m long decimeter sticks
- Two 1.000-m long centimeter sticks
- Two straight rods (wood or metal) that differ in length by 1 cm; e.g., 0.32 m and 0.33 m.

Optional items are

- Two uncalibrated 1.000-yd long sticks
- Two 30-cm purchased rulers marked at each mm
- Two glass rods that differ in length by 0.5 mm; e.g., 27.23 cm and 27.28 cm in length
- Two magnifying glasses

Six wooden sticks 1.000 m in length and two wooden sticks 1.000 yd in length must be prepared in-house. Calibration marks one decimeter apart on two of these meter sticks and one centimeter apart on two others can be drawn with a pencil.

The two glass rods of near equal lengths are prepared by cutting two rods of equal length (about 27 cm) and fire polishing the ends. If one is not about 0.5 mm longer than the other, then shorten one rod by heating one end and gently pressing it on a hard, flat surface. If each glass rod is wrapped with tape of a different color, they are easily identified and do not become a hazard if broken.

### The Classroom Demonstration

A teacher, who is holding in each hand one metal or wooden rod, poses to the class, "Are the lengths of these rods identical?" Students accept the notion that no two rods are likely to have exactly the same length. The teacher then moves to the more important question, "How many significant figures must be in the measurements of the lengths of these two rods in order to know that their lengths are different?"

Two students selected by the teacher are each given one of the two rods. Each student is to use an unmarked meter stick to measure the length of his or her rod and record the result on the chalkboard. The students can make their measurements only by estimating the rod's length to the nearest tenth of a meter. This has been a learning experience for many students in both estimating length and understanding the uncertainty that exists as a part of every measurement.

The lengths of these two rods cannot be distinguished by measurements having only one significant figure. Another measuring instrument must be employed to distinguish between them. The teacher can then proceed with the demonstration by first selecting students to measure the rods' lengths by use of a decimeter-marked meter stick (two significant figures) and finally by using a centimeter-marked meter stick (three significant figures). Only when the lengths are measured to three significant figures can the two rods be distinguished.

Some students usually suggest that it would be easier to determine if the lengths of the rods differ by avoiding measurement altogether. By standing the two rods on a table top, a person could easily identify the taller rod. Sure, but this is a measurement. It is the comparison of the length of one rod with the length of the other rod rather than with the length of another arbitrary standard. All measurements are a comparison of a physical property of one object with that of a standard, which will always yield a measurement having an uncertainty and a unit. Only counting, a one-to-one correspondence between items and integers, could yield a numerical result without an uncertainty and a unit of a physical quantity.

Upon standing the rods side-by-side on a tabletop, one of the rods is perceptibly longer than the other. This demonstration shows the students how much the lengths of two rods may differ and yet require a measurement of three significant figures in order to distinguish between them. Would standing the rods side-by-side be an acceptable way to determine the longer if one rod were in Memphis and the other in New Orleans?

### Options To Consider

The teacher may alter or extend this demonstration. First, after the students have measured the lengths of the wooden or metal rods to one significant figure, ask them to repeat their measurement by use of an unmarked yardstick. The class should observe that a measurement of only one significant figure is all that can be obtained by use of either of these instruments, but the unit employed to record the measurements will certainly be different. The demonstration may be stopped at this point if the single purpose is to show that the system of units employed to describe a measurement does not improve the accuracy of a measurement.

A second option is open to teachers who feel that their students need a bigger challenge. The teacher can show the class two new rods side-by-side that have lengths so close that the class cannot distinguish the longer. The teacher can ask the class, "Could a measurement having four significant figures distinguish between the lengths of these two rods?"

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Select two students to measure the lengths of the glass rods by use of purchased meter sticks with calibration marks at each millimeter of length. The students can swap meter sticks and/or rods and measure the lengths again. Almost all students need to be instructed about parallax errors during this demonstration. If the zero point of the metric rule is not at the ruler's end, or if the end is worn, the students should be reminded that they should not measure a length beginning at the extreme end of the ruler. Students able to measure lengths to four significant figures can show that the two rods do have different lengths.

During these demonstrations students observe that two rods that are obviously different in length are the same length to one and even two significant figures, but two rods that appear side-by-side to be the same length can be shown to have different lengths if measurements of their lengths are made correctly to four significant figures. The teacher has several opportunities to teach important knowledge about significant figures, units, measurements, and the uncertainty of measurements during this series of demonstrations.

# Introductory Laboratory Exercises

**Susan Wells Rollinson**
Dabney S. Lancaster Community College, Clifton Forge, VA 24422

A perennial problem with General Chemistry courses is how to handle labs during the drop–add period, when class rolls are fluctuating. I wish to describe the exercises we use for the first two weeks of General Chemistry that minimize the problem. As these procedures do not require the use of individual equipment, student lab drawers are not assigned until the third week, when enrollment has stabilized. High school chemistry teachers might also want to consider these exercises since they require minimal equipment and are easily adapted to suit the instructor.

This introductory lab consists of several procedures. Some are performed as demonstrations. Others are performed by groups of two students. In two cases, the exercise requires data contributed by every class member. The nature of the procedures also make them serve as an "ice-breaker", introducing the students (and instructor) to one another.

I usually have a computer in the lab on which the data can be "instantly" reduced and plotted. At the conclusion of the experiments, each student must present his or her data analysis in a brief lab report.

### Learning Objectives

These exercises can be used to fulfill several educational objectives commonly found at the beginning of general chemistry. The student will be able to

use the triple beam and analytical balances,
use metric system units of mass, length, and temperature,
graph linear relationships and reduce simple nonlinear relationships to linear ones,
determine the slope and intercept of a linear graph and extrapolate to extreme or impossible experimental conditions,
use significant digits properly,
understand the relationship between significant digits and the precision of laboratory measurements, and
use computer spreadsheet programs to reduce data and perform linear regression.

Additionally, these exercises provide material for a review of algebra and help students acquire confidence with the metric system and the chemistry laboratory.

### Linear Graphs

We start with a selection of simple experiments that produce linear graphs. Using either a physician's scale or a bathroom scale, the mass of a student is measured in kilograms while holding 2, 3, 5, 7, and 10 copies of the chemistry textbook. (Choose a volunteer with strong arms, as 10 textbooks may weigh 50 pounds!) Plotting the mass against the number of textbooks produces a linear graph. The mass of the textbook can be found from the slope of the line, while the intercept reveals the mass of the volunteer.

The next experiment gives an estimate for the value of absolute zero. A hollow metal sphere filled with air is connected to a pressure gauge (Fig. 1).[1] A minimum of four pressure readings are taken at temperatures ranging from 0 to 100 °C. The resulting linear graph of temperature against pressure is extrapolated to zero pressure and an estimate for absolute zero is made.

The last "linear" experiment requires taking the temperature of several water baths with both Fahrenheit and Celsius thermometers. (Ice/salt, ice, cold water, room-temperature water, hot water, and boiling water make a convenient range of temperatures.) A graphical comparison of the temperature scales is made, and the experimental equation is compared to the exact relationship between the temperature scales.

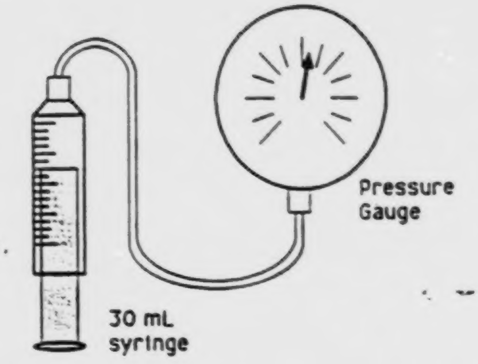

Figure 1. Pressure–volume apparatus.

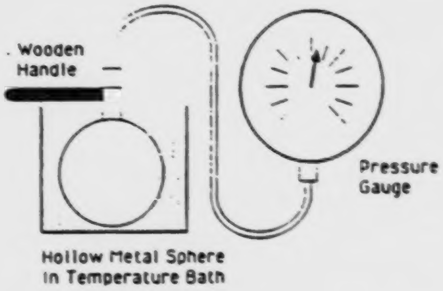

Figure 2. Absolute zero apparatus.

### Nonlinear Graphs

We do two experiments that result in nonlinear graphs. First we do a P–V plot with data taken from a 30-mL syringe connected to a pressure gauge (Fig. 2).[2] The students are led to discover that a plot of $P$ against $1/V$ (or $V$ against $1/P$) is linear.

Second, the mass of a series of rubber stoppers (six to eight stoppers ranging in size from 00 to 8) is compared to the average of the top and bottom diameters.[3] Of course, the stoppers must all be made of the same rubber! A plot of mass against diameter gives a parabolic curve and the students are led to discover that mass vs. the square of the diameter is a linear relationship.

---

[1] Absolute Zero Unit. Educational Materials and Equipment Company, 46 Lafayette Ave., New Rochelle, NY 10801. Available through Sargent–Welch (cat. no. 1602) or Frey Scientific (cat. no. 7536).

[2] Boyle's Law Unit. Educational Materials and Equipment Company. Available through Sargent–Welch (cat. no. 1077D) or Frey Scientific (cat. no. 7536).

[3] Abraham, M. R.; Pavelich, M. J. *Inquiries into Chemistry*; Waveland: Prospect Heights, IL 1979; p 16. This text is a good source for other "guided inquiry" experiments.

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### "Scatter" Graph

Each student must contribute his/her height in centimeters and mass in kilograms to a class chart. The instructor and lab assistant also participate. A plot of height against weight usually gives widely scattered points around a trend toward taller people weighing more than shorter people. All height and weight data are, of course, anonymous. This, along with the metric units, has prevented complaints of embarassment! We also discuss whether other variables, such as age, should be considered.

### Precision of Measurement

A final exercise is performed to give the class a feel for the precision of laboratory balances. Four objects (a sheet of filter paper, a ball-point pen, a 100-mL beaker, and a rubber stopper) are weighed on both the triple-beam and analytical balances. Then all four objects are placed on the pan of each balance and weighed. Everyone in the class uses the identical objects and balances. The class data are pooled and several comparisons are made: The calculated sum of the four objects is compared with the measured sum. The average mass of each object and the average deviation for each is calculated. The precision of the triple-beam and analytical balances are compared.

### Summary

The use of several short introductory experiments has allowed us to present meaningful experiences to our general chemistry students without having to assign lab drawers in the first two weeks of the term. These exercises introduce the students to the metric system, balances, significant digits, graphing, and computerized data analysis.

# A Paper Vernier Scale for Various Laboratory Equipment

**B. S. Lark**
Guru Nanak Dev University, Amritsar-143 005, India

Working in the chemistry laboratory and observing the students carry out a variety of experiments on simple graduated pieces of equipment like a buret or cylinder, I saw the general difficulty students encounter in reading the level correctly, especially when it lies anywhere between the two graduation marks. The students are customarily told to ignore the contributions that are less than half the minimum graduation interval and—if the interval is half or more than half—to take a full unit contribution.

Students often reject this idea, nor do I like to stress the conventional process. Often I advise them to guess the fraction of the interval: This is better than ignoring it totally or considering it as a full unit contribution. However, this always pricks my sense of precision. So I recommend construction of a convenient vernier scale (see figure, part a) made of chart paper. This simple tool can easily improve the readability of the scale by 10 times and, with extra care, by 20 times or more.

## Construction

An ordinary 50-mL buret is divided into 50 1-mL divisions, and each 1-mL interval is further divided into 10 parts to read up to 0.1 mL. To construct a vernier scale for such a buret, take a piece of clean, white, thick, chart paper that is tough enough to stand erect and place its one sharply cut edge vertically against the scale of the buret. Then with a very sharp pencil, mark two points on the edge of the paper to correspond to the nine small scale divisions on the buret.

On another piece of paper a straight line is drawn, and line segment *AB* equal to the measured length is marked. (If a divider is available, measuring the distance between nine scale divisions and marking on a line can be achieved easily). Then starting from the point *A*, a straight line at an acute angle (preferably between 40 to 60°) is drawn. Either with a divider/compass or pen and scale, 10 intervals up to point *C* are marked (each interval may be 0.5 cm in length). Points *B* and *C* are joined; using a very sharp 2H pencil, lines parallel to *BC* are drawn to divide *AB* into 10 parts (figure, part b).

Now the scale is ready. Either on the same paper or a separate, thick, white, chart paper, the scale is transferred and may even be extended on either side. Then a slit $S_0$ is cut adjoining the scale (figure, part a). Two more, $S_1$ and $S_2$, 2-mm-wide and 5-cm long slits are cut on the paper with the help of a sharp blade and scale. Slits $S_1$ and $S_2$ are used to slip the vernier scale on the buret as shown (figure, part c).

## Use

Use of the vernier is very simple. Through $S_1$ and $S_2$, it is slid on the buret or the apparatus for which it is made. The level and zero of the vernier scale are made to align by sliding the vernier-scale card gently. Then the lines on the buret scale and the vernier scale that align are noted, and the reading is taken as usual. A hand lens may be used to facilitate the judgment of matching the lines.

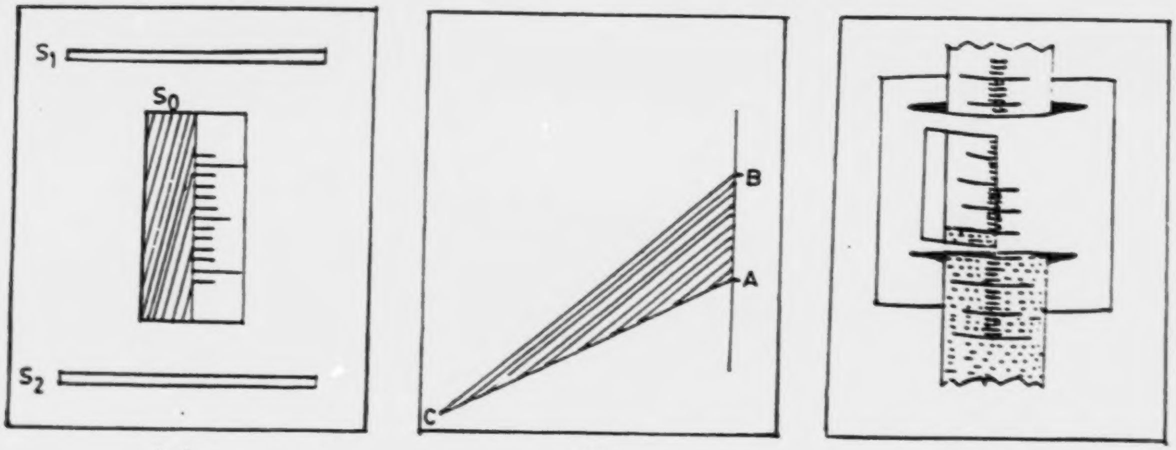
### *Application*

Various pieces of equipment to which this vernier scale can be fixed are

- buret
- graduated cylinder
- thermometer
- dilatometer
- graduated stem of a stalagmometer
- surface tension by capillary-rise method

### *Extension of the Scale*

Precision can be extended to 0.05 (or even more under suitable conditions) by dividing a line segment equal to 19 intervals into 20 equal parts.



(a) (b) (c)

Construction of the vernier and its use with a buret.

KELLEY 28

# Teaching Dilutions

**Lloyd J. McElroy**
The Pennsylvania State University Beaver Campus
Monaca, PA 15061

Many branches of sciences use dilutions for laboratory protocols. Dilution applications range from diluting standardized stock solutions of various chemicals to procedures used for counting procaryotic and eucaryotic cells and virus plaques. Despite the requirements for a working knowledge of dilutions, the concepts appear to be difficult for many students to grasp. However, graphic presentations help students to visualize the dilution process when presented along with mathematical relationships. The following graphic examples have proven successful in my classes.

## Basic Concepts

The substance used for diluting is called the "diluent". Usually, this is water, but it can be any other solvent. The material to be diluted may be another liquid, a solid, suspended particles, or cells. Because this material occupies a certain volume itself, the total volume consists of the diluted material and the diluent. It often is convenient to refer to these volumes as parts. For example, 1 mL of a substance diluted with 9 mL of water is one part in nine parts of diluent. "Parts" can be milliliters, gallons, or buckets, etc. Figures one through four emphasize the basic concept that the product (amount/volume)(volume) before dilution equal the product (amount/volume)(volume) after dilution. If any three quantities are known, the fourth can be calculated easily. Therefore, in Figure 1:

| *Before Dilution* | | *After Dilution* |
|---|---|---|
| (10 cells/1 mL)(1 mL) | or | (1 cell/1 mL)(10 mL) |
| $M_1 V_1$ | = | $M_2 V_2$ |

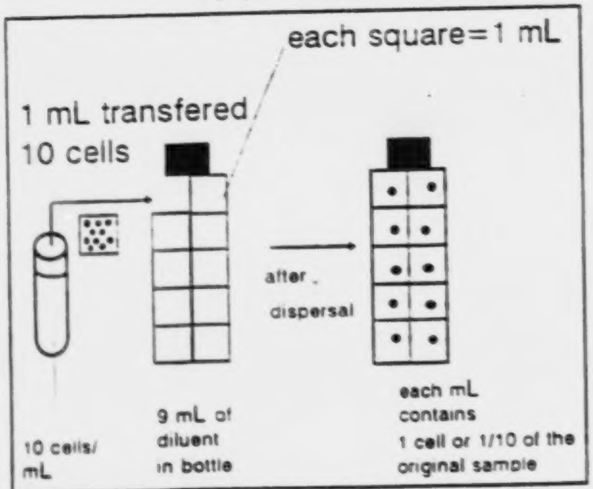

each square=1 mL
1 mL transfered
10 cells
after
dispersal
10 cells/
mL
9 mL of
diluent
in bottle
each mL
contains
1 cell or 1/10 of the
original sample

Figure 1. A one to 10 dilution with 9 mL of diluent.

Thus, one part containing 10 cells or molecules, etc. were dispersed evenly, *after appropriate mixing*, in nine parts of diluent. Each part or milliliter in the resulting total volume now contains only one cell or 1/10th of what we started with; hence, we have a 1:10 dilution. In addition, any fraction or multiple of the one part in nine parts also is a 1:10 dilution. For example: 0.1 part in 0.9 parts, 0.01 part in 0.09 parts, 0.5 parts in 4.5 parts, 2.0 parts in 18 parts. All are 1:10 dilutions.

Application of this concept to Figures 2 and 3 gives the following relationships.

| | *Before Dilution* | | *After Dilution* |
|---|---|---|---|
| Figure 2 | (10 cells/1 mL)(2 mL) | = | (1 cell/1 mL)(20 mL)<br>a 1:10 dilution |
| Figure 3 | (10 cells/1 mL)(1 mL) | = | 2 cells/1 mL)(5 mL)<br>( a 1:5 dilution |

## Serial Dilutions

Some applications such as chemical gradients for producing standard concentration curves or diluting cell sus-

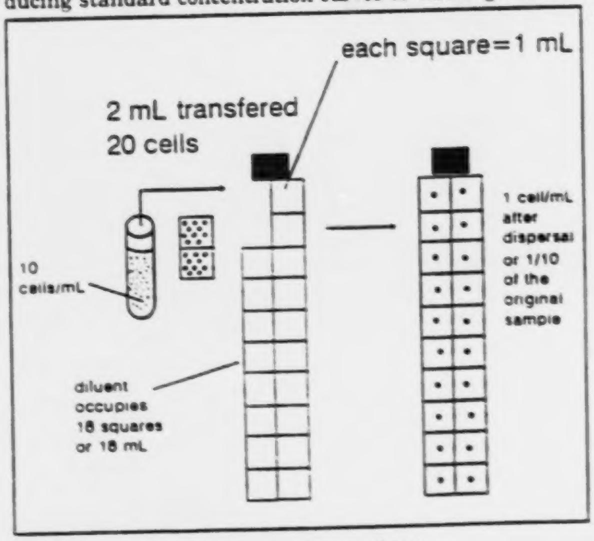

each square=1 mL
2 mL transfered
20 cells
10 cells/mL
diluent occupies 18 squares or 18 mL
1 cell/mL after dispersal or 1/10 of the original sample

Figure 2. A 1-to-10 dilution with 18 mL of diluent.

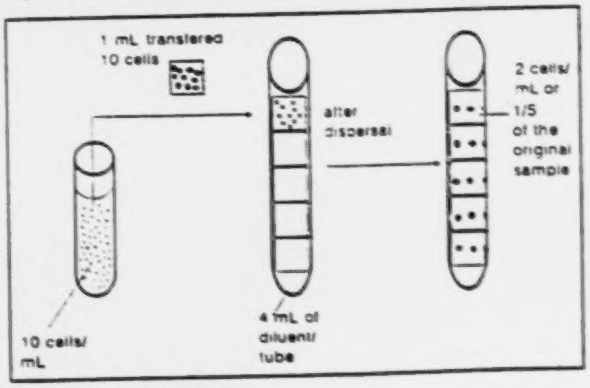

1 mL transfered
10 cells
after dispersal
2 cells/ mL or 1/5 of the original sample
10 cells/ mL
4 mL of diluent/ tube

Figure 3. A 1-to-5 dilution.

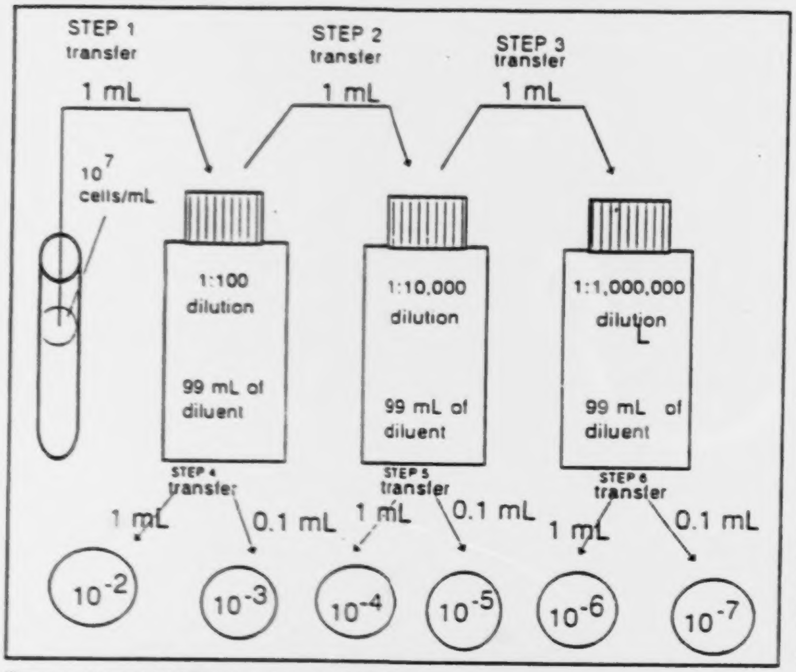

STEP 1
transfer
1 mL
STEP 2
transfer
1 mL
STEP 3
transfer
1 mL
$10^7$ cells/mL
1:100 dilution
99 mL of diluent
1:10,000 dilution
99 mL of diluent
1:1,000,000 dilution
99 mL of diluent
STEP 4
transfer
1 mL
0.1 mL
STEP 5
transfer
1 mL
0.1 mL
STEP 6
transfer
1 mL
0.1 mL
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$

Figure 4. A serial dilution used with a standard cell count procedure.

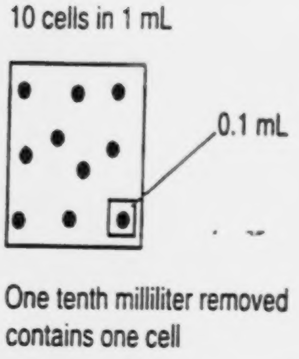

10 cells in 1 mL
0.1 mL
One tenth milliliter removed contains one cell

Figure 5. Another method of doing a 1-to-10 dilution.

pensions for bacterial plate counts, require dilutions to be done over a series of steps or serial dilutions. This provides increments or a gradient of the original sample. In Figure 4, each bottle represents a 1:100 dilution (one part distributed in 99 parts of additional diluent). However, in a serial dilution, each subsequent dilution becomes a multiple of each of the preceding individual dilutions. Therefore, our bottles, while each being a 1:100 dilution by themselves, collectively will be a 1:100, 1:10,000, and 1:1,000,000, respectively (i.e., 100 × 100 × 100). If we were using this technique to count bacterial cells and our original sample contained 10 million cells/mL, then our first bottle would contain 1/100th of the original sample or 100,000 cells/mL. The second bottle would contain 1/10,000th or 1000 cells/mL, and the third would hold 1/1,000,000th or 10 cells/mL. The increments in this serial dilution are 100-fold in each step. In some instances, these steps may be too large, and intermediate dilutions providing smaller increments are desirable. For example, the standard plate count technique–used for counting bacteria in water samples and other media–allows counting only those Petri dishes containing 30 to 300 colonies. This could be accomplished by doing intermediate 1:10 dilutions. For instance, remove 1 mL from each of the dilution bottles and place it in an additional 9 mL of diluent. This would give us gradient steps of 1:1000, 1:100,000, and 1:10,000,000, respectively. However, an easier way would be simply to remove 1/10th as much from each dilution bottle or 0.1 mL and transfer this to our Petri dishes. This, in effect, is the same as doing a 1:10 dilution (See Fig. 5). The final dilutions in our Petri dishes then become $10^{-2}$, $10^{-3}$, $10^{-4}$, $10^{-5}$, $10^{-6}$, and $10^{-7}$, respectively, as shown at the bottom of Figure 4. The number of cells in our original sample is determined by multiplying the colonies that appear on the Petri dish times the dilution to get cells per milliliter. The table shows the relationships between the dilution factor and cell counts.

**Dilutions and Relation to Cell Counts**

| Dilution | Colonies Expected | Cells/mL in Undiluted Sample |
|---|---|---|
| 1:100 | 100,000 | 10,000,000 |
| 1:1,000 | 10,000 | 10,000,000 |
| 1:10,000 | 1,000 | 10,000,000 |
| 1:100,000 | 100 | 10,000,000 |
| 1:1,000,000 | 10 | 10,000,000 |
| 1:10,000,000 | 1 | 10,000,000 |

Colonies × dilution = cells/mL in original sample

## Conclusion

The graphic presentations—the only true way to grasp these concepts—have helped my students visualize what is happening during the dilution process, instead of just learning formulas by rote through numerous dilution problems. Innovative laboratory applications will transfer dilution theories into practice.

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**Linda Rhoden**
**Composite Science**
**J.F. Dobie High School, Pasadena ISD**

**Fina Research & Development Technical Center, Deer Park**
**Dr. Jose Sosa, Mentor**
**Lu Ann Kelly, Mentor**

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## *TTIP*
## *Curriculum Implementation Abstract*

Name: Linda Rhoden

Internship: Fina Oil and Chemical

School: J.Frank Dobie High School

Primary Subject: Physical Science / Environmental Science

Activities: I. Periodic Table
"Who Am I?"puzzle
Reviewing Properties of Elements / Mixed Sixes. Elementary My Dear Watson

II. Monomers and Polymers
Naming Hydrocarbons
Constructing a Nylon Polymer Molecule
Paper Clip Model

III. Recycling
"Paper or Plastic?"
Recycling Codes and Examples
Plastic Bag Information Clearing House
Puzzles: Plastic Crossword / Petroleum Scramble
Petrochemical Word Find

IV. Use Your Mind or Lose Your Money
Game Rules
Currency Sheets
Net Profit Sheet

V. Film Line Case Study
Wrap It Up Case Study
Question Sheet

VI. Control Charting
"Are You Out Of Control?"
Data Tables
Graph Sheets
Graphed Data

Summary: These lessons will provide the student with a basic chemical background enabling them to identify patterns within the periodic table, and name and identify hydrocarbons.

The structure of hydrocarbons will be expanded and applied to the formation of the various types of plastics. This information in turn will be applied to the recyclability of different plastics.

Critical thinking and problem solving skills inherent to the scientific method will be applied to everyday workplace situation .

Resources:
Dr. Jose Sosa
Dr. Mark Kuchenmeister
Luann Kelly
Greg Kaase
Fina Research and Technology Center
Hwy 134 @ Miller Cutoff
Deer Park, Tx

Continuous Improvement of Quality
Associates in Process Improvement
Austin, Tx

Fundamentals of Chemistry
Third Edition
James E. Brady
John R. Halum
John Wiley and Sons, Inc.

Prentice-Hall Physical Science
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Laidlaw Physical Science
Laidlaw Publishing, Inc.

The Plastic Bag Information Clearinghouse
1817 E. Carson St.
Pittsburgh, Pa 15203

# Periodic Table Activities
## Teacher Notes

***Objective:*** Students will use basic periodic table information to identify patterns in the arrangement of the elements, and use this information to predict and make inferences regarding the chemical and physical properties of certain elements and families.

***Materials:***
1. Periodic Table Background Information Sheet
2. Puzzle ; Who Am I ?
3. Reviewing Properties of Elements on the Periodic Table / Mixed Sixes - Elementary , My Dear Watson

## *Periodic Table Background Information*

By the middle of the nineteenth century, many of the quantitative laws of chemistry had been discovered, which allowed scientists to gather a wealth of empirical facts about the chemical and physical properties of the elements. To make sense of it all, and to use the information effectively, the information needed to be organized. In this way, important similarities, differences, and trends can be seen. Finding these relationships can help understand why certain elements are metals and others are nonmetals, and why certain elements often form ionic compounds while others seldom do..

Numerous attempts were made to discover relationships among the chemical and physical properties of the elements. A number of different sequences of elements were tried in search of some sort of order or pattern. A few of these arrangements came close, in some respects, to our present table, but were in some way flawed, or perhaps presented to the scientific community in a manner that did not lead to their acceptance.

The current periodic table is based primarily on the efforts of a Russian chemist, Dmitri Ivanovich Mendeleev (1834-1907), and a German physicist, Julius Lothar Mayer (1830-1895). Working independently, these scientists developed similar periodic tables only a few months apart in 1869. Because he had the good fortune to publish first, Mendeleev is usually given credit for the periodic table in which he arranged the elements in order of increasing atomic weight. He found that similar chemical properties occurred over and over again at regular intervals.

The table that Mendeleev developed is in many ways similar to the one we use today, however, in our modern periodic table the elements are arranged in horizontal rows called *periods*, in order of their increasing atomic number. The fact that it is the atomic number - the number of protons in the nucleus of and atom- that determines the order of elements in the table has very important implications with regard to the relationship between the number of electrons in an atom and the atom's chemical properties.

Elements in the vertical columns known as groups bear similarities to each other and so are frequently referred to as *families*. Elements are classified as metals, nonmetals, or metalloids according to such properties as ability to gain or lose valence electron, electrical conductivity and luster.

Family I-A elements ( Alkali metals) are very chemically active metals, that tend to become positive ions when they give away their one valence electron. Elements in Family VII-A (Halogens) are very chemically active nonmetals, that tend to become negative ions when they attract the one additional valence electron necessary to complete their outermost energy level. Elements in Families I-VIII B are metallic in nature , but because the number of electrons that they can give away varies, these are called the *transition metals*. Elements in Family VIII-A (Noble gases) have a very limited degree of chemical activity, due to their complete outermost energy level.

The periodic table is an important tool to chemists and chemistry students, because it allows us to study systematically the way properties vary with an element's position within the table and, it turn, makes the similarities and differences among the elements easier to understand and remember.

### ***Periodic Table Background Information***

Practice Exercise 1. Representative elements are K, Cr, Pr, Ar, Al. Family __________

2. A halogen is Na, Fe, O, Cl, Cu. __________

3. An alkali metal is Zn, Ag, Br, Ca, Li. __________

Name ______________________ Class ______________ Date ______________

# Who Am I?

The following chart contains clues about the identities of some of the elements in the periodic table.

1. Read each description and then identify the area of the periodic table in which the element would most likely be found.
2. Fill in the appropriate space in the chart using the name of the family or general category of elements.
3. In the next column, write the symbol for the possible identity of the element being described.

| Description | Area | Element |
|---|---|---|
| 1. I have very good ability to conduct electricity. I am never found alone in nature. When I combine with other elements, I usually give up my one valence electron. I am the only element in my group with a one-letter symbol. | | |
| 2. I do not conduct electricity and am usually found in the gaseous state. I do not bond well with other elements. I can be found in some bulbs used in signs. | | |
| 3. I am a gas, but I combine very easily with many other elements. I usually form ionic bonds. I frequently form a −1 ion in those ionic bonds. I am the lightest element in my group. | | |
| 4. I am a very tough, durable element. I can give up two electrons, but I sometimes give up more than two when bonding. I am the main element found in steel. | | |
| 5. I am never found alone or unbonded in nature. I most commonly form a +2 ion when bonding. I have the second highest number of protons in my family. | | |
| 6. In my family the elements are all metals except for me. I have three valence electrons. | | |
| 7. Although I am in a family of nonmetals, I am found as a solid. If I combine with calcium, two atoms of me but only one atom of calcium are required. | | |
| 8. I usually form covalent bonds. I have five valence electrons. I have the highest atomic mass in my group. | | |
| 9. In my family there are nonmetals, metalloids, and metals. I have the same number of protons as the sum of the protons in the two elements directly above me in the periodic table. | | |
| 10. Elements in my family usually form covalent bonds. We have two fewer valence electrons than noble gases. I am almost twice as heavy as the lightest element in my group. | | |

Name ______________________ Date ______________

## MIXED SIXES

The six scrambled words in Column 1 fit the definition or description given in Column 2. Unscramble the words and write them in Column 3. Then unscramble the circled letters in Column 3 to find the group containing the most active nonmetals.

| Column 1 | | | | | | Column 2 | Column 3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | R | N | O | A | C | An element in coal. | | ○ | | | | |
| L | I | H | M | E | U | A noble gas. | ○ | | ○ | | | |
| G | X | E | O | N | Y | An element needed for burning. | ○ | | | ○ | | |
| E | I | D | I | O | N | A halogen. | | | | | ○ | |
| P | C | P | O | R | E | A metal. | | | | | ○ | |
| D | U | M | S | O | I | Explodes when dropped into water. | ○ | | | | | |

The most active nonmetals are the ______________________________________________

## ELEMENTARY, MY DEAR WATSON

For each clue that you discover, write the missing element in the blanks to the right. Then to discover the missing word that the chemist said, you must transfer the correct letters to the numbered blanks.

1. It is the element in Period 5 of Group VIIA. $\underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underset{2}{\underline{\quad}}\ \underline{\quad}\ \underline{\quad}$
2. Its atomic number is 90. $\underset{6}{\underline{\quad}}\ \underset{7}{\underline{\quad}}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underset{4}{\underline{\quad}}$
3. Its average atomic mass is 150.4. $\underset{3}{\underline{\quad}}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}$
4. It is the lightest metalloid. $\underset{1}{\underline{\quad}}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}$
5. It is the fourth member of the actinide series. $\underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underline{\quad}\ \underset{5}{\underline{\quad}}$

What did the chemist say to the first customer of the day? "Open for $\underset{1}{\underline{\quad}}\ \underset{2}{\underline{\quad}}\ \underset{3}{\underline{\quad}}\ \underset{4}{\underline{\quad}}\ \underset{5}{\underline{\quad}}\ \underset{6}{\underline{\quad}}\ \underset{7}{\underline{\quad}}$."

## *Monomer / Polymer*

### Teacher Notes

The term monomer is derived from ***Mono***- one and ***mer***- unit, so one paper clip can be used to represent a monomer, two paper clips connected a dimer, three clips connected a trimer, etc. Joining ***many*** clips together in a long chain then represents a ***polymer*** .

Polymers vary in the number of monomers required to achieve the desired properties for that particular substance. For instance, nylon requires only 50 to 60 adipic acid and hexamethylenediamine monomers to obtain the properties of nylon which enable it to be drawn into fibers, if more than 100 monomers are connected, the polymer becomes too viscous to be drawn into fibers. Conversely a minimum of 30,000 ethylene monomers must be linked into a chain in order for any polyethelyene properties to be exhibited.

To demonstrate the differences among the various types of polymers, chains of paper clips can be linked together. An additional clip can be attached forming a bridge between two of the already existing chains to represent crosslinks. Forming several long chains of paper clips will demonstrate how polymer chains interact. Much like a bowl of spaghetti, chains are entangled, but are still capable of being individually separated. Crosslinks however, prevent the individual chains from moving independently of each other.

Silly putty, superballs, golf balls, rubber bands, balloons, punch balls, etc. can be used as examples.

## *Monomers / Polymers*

Molecules of organic compounds of carbon nearly always have chains of two or more carbon atoms or rings of three or more. These chains and rings serve as the framework to which other nonmetal atoms, especially hydrogen but also oxygen, nitrogen, sulfur or any of the halogens, are covalently attached. There are also organometallic compounds in which metal atoms are attached by electron pair bonds.

Virtually all plastics, synthetic and natural fibers, dyes and drugs, insecticides and herbicides, ingredients in perfumes and flavoring agents, and all petroleum products are organic compounds. The naming of the basic organic compounds composed of carbon and hydrogen atoms only is based on a relatively simple system of prefixes which indicate the number of carbon atoms present in the compound, and a formula which then uses the number of carbon atoms, to determine the number of hydrogen atoms and the type of covalent bond present.

| ***Prefixes*** | ***( # of Carbon atoms)*** |
|---|---|
| Meth- | 1 |
| Eth- | 2 |
| Pro- | 3 |
| But | 4 |
| Pent- | 5 |
| Hex- | 6 |
| Hept- | 7 |
| Oct- | 8 |
| Non- | 9 |
| Dec- | 10 |

| ***Suffixes*** | |
|---|---|
| -ane | saturated , single bonds<br>$C_n H_{2n+2}$ |
| -ene | unsaturated, at least one double bond<br>$C_n H_{2n-2}$ |
| -yne | unsaturated, at least one triple bond<br>$C_{n^{\circ}} H_{2n}$ |

***For example:***

| | | | | |
|---|---|---|---|---|
| Methane | *Meth-* | 1 carbon, *-ane* | $C_nH_{2n+2}$<br>$C_1H_{(2x1+2)}$ | $= CH_4$ |
| Pentene | *Pent-* | 5 carbons, *-ene* | $C_nH_{2n-2}$<br>$C_5H_{(2x5-2)}$ | $= C_5H_8$ |
| Heptyne | *Hept-* | 7 carbons, *-yne* | $C_nH_{2n}$<br>$C_7H_{(2x7)}$ | $= C_7H_{14}$ |

Name ______________________ Class ______________ Date ____________

Chapter 10

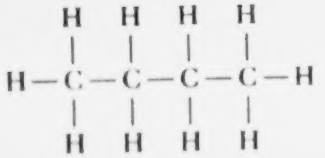
Using Science Skills: Applying definitions

# Naming Hydrocarbons

Hydrocarbons are compounds made up of carbon and hydrogen. Hydrocarbons called the alkanes are the simplest hydrocarbons. These compounds are named by using a prefix that tells the number of carbon atoms they contain and the root "ane."

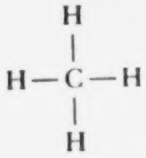
Using the table below, name each of the alkanes that are shown.

| Prefix | Number of Carbon Atoms |
|---|---|
| meth- | 1 |
| eth- | 2 |
| prop- | 3 |
| but- | 4 |
| pent- | 5 |
| hex- | 6 |
| hept- | 7 |
| oct- | 8 |
| non- | 9 |
| dec- | 10 |



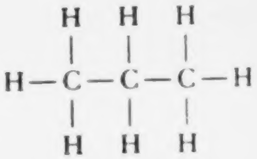
$$\begin{array}{ccccccccccc} & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & \end{array}$$

1. ____________________



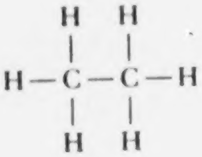
$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & H \\ & & | & & \\ & & H & & \end{array}$$

2. ____________________



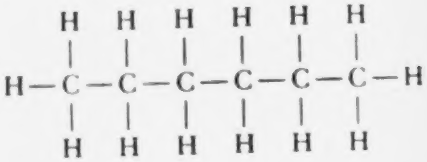
$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

3. ____________________



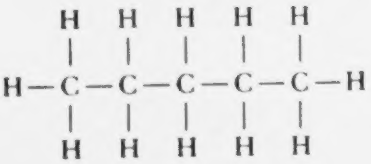
$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

4. ____________________



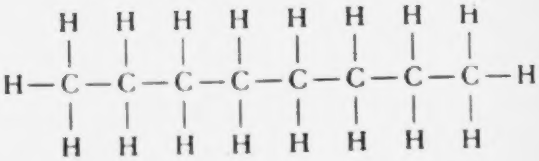
$$\begin{array}{ccccccccccccccc} & & H & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & H & & \end{array}$$

5. ____________________



$$\begin{array}{ccccccccccccc} & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & \end{array}$$

6. ____________________



$$\begin{array}{ccccccccccccccccccc} & & H & & H & & H & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & H & & H & & H & & \end{array}$$

7. ____________________

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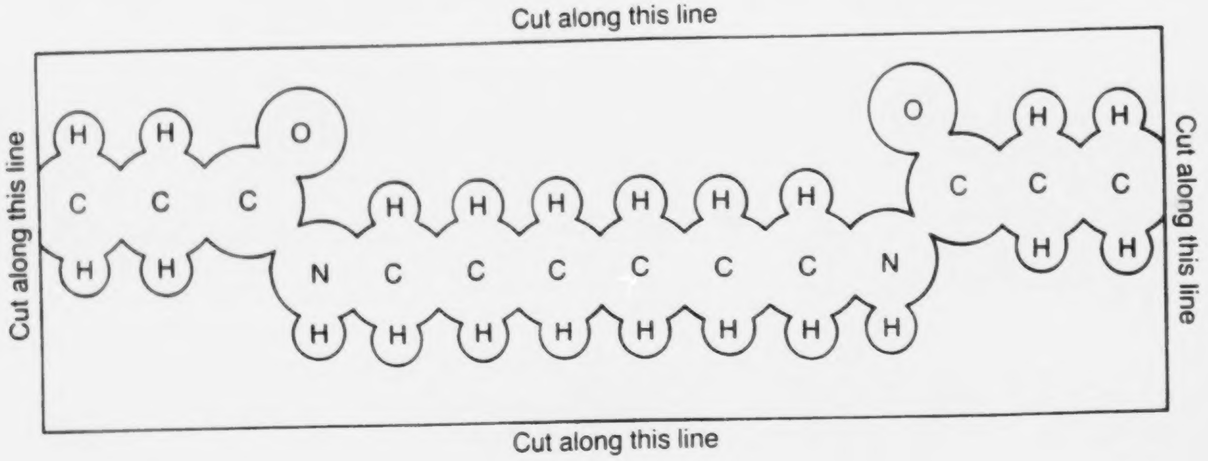
Name ______________________ Class ________________ Date ______________

Chapter 27 Using Science Skills: Developing a model

# Constructing a Nylon Polymer Molecule

The molecule in the diagram below is a *monomer* of nylon. A monomer is a single unit of atoms that is repeated over and over again to form a chained molecule called a *polymer*. In this activity, you will construct a model of the nylon polymer. All you need to do this is paper, scissors, and a stapler. Follow the steps listed below and have fun while making nylon.

1. Cut out the rectangular box along the lines indicated in the diagram below.
2. Cut three more rectangular boxes exactly like this one from another piece of paper.
3. Tape the four pieces (the original and three copies) end-to-end. You should have one long, narrow strip of paper.
4. Fold the paper accordion style (like a fan) *at the adjoined ends*. Make sure your original is on top and the outline of the atoms is showing.
5. Staple the four folded sections together at each corner. *Do not staple over the outline of the atoms*.
6. Now cut along the outline of the atoms. Do this slowly and carefully.
7. Unfold your masterpiece. You now have a nylon polymer. Label each atom with the appropriate symbol.



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## *"Paper or Plastic?"*

Teacher Notes

You may want to introduce this lesson with examples of each of the different types of plastics on your desk, or you may want to give the properties of each type and then ask students what kind of products might be made from these polymers.

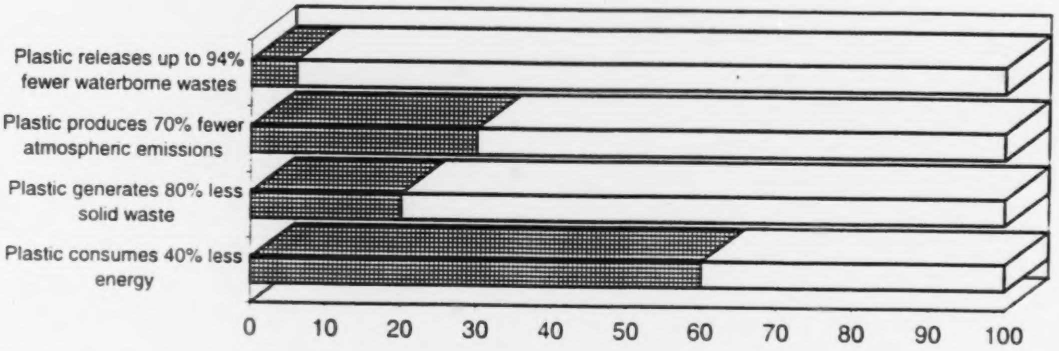
Some examples: teflon tape, milk jugs, stick Crisco container, different brands of yogurt containers, styrofoam cups, ice chests, Solo (type) cups, pudding and margarine containers, Ziploc bags, Saran wrap, Barbie dolls( hair, head, body), clear plastic glasses.

## *"Paper or Plastic ?"*

How do you respond to this question at the grocery store? Which do you choose and why? Which choice is more earth friendly?

When a retailer offers its customers plastic bags, it is offering the customers an environmental shopping choice. Why? Because plastic bags are friendlier to the environment than paper bags.

Franklin Associates, Ltd. compared the environmental effects of producing, using, recycling and disposing of plastic vs. paper bags. The study results may be a surprise.



Plastic bags are also more economical than paper bags, and consumers find them handy to reuse and convenient to recycle. Truly environmental shoppers choose plastic!

45

1

**PET** - Polyethylene Terephthalate
beverage bottles, apparel, upholstery, films and tapes, tire cord, conveyor
belts, adhesives, recreational items

2

**HDPE** - High Density Polyethylene
one gallon milk jugs, pipe and tubing,, oil cans, housewares (Tupperware), caps and lids

3

**PVC** - Polyvinyl Chloride
plumbing pipes, latex paints, flexible film, food wrap (Saran, Handiwrap), house siding, garbage bags, appliance parts

4

**LDPE** - Low Density Polyethylene
grocery bags, diaper covers, packaging film, toys

5

**PP** - Polypropylene
brushes, carpet, carpet backing, rope, strapping tape, toys, film sheeting, plastic bottles, rigid packaging, appliance parts

6

**PS** - Polystyrene
drinking cups, food packaging, housewares, furniture, appliance parts, electrical components, electronic components, polishes, medical and dental products

7

**Other**
cream jars, Mott's apple sauce

# GET IN THE HABIT!

## SURVEY

In a recent survey members of the Plastic Bag Association's Consumer Advisory Board reviewed their shopping habits of today, compared to five years ago. More than 90 percent rated their environmental shopping behavior as improved.

| | 1990 | 1996 |
|---|---|---|
| **Choosing Products with Reduced Packaging**<br>Over 90 percent of those surveyed say they "often" or "sometimes" buy products with reduced packaging, compared with less than 40 percent five years ago. | 40% | 90% |
| **Buying Products in Recyclable Packaging**<br>Nearly 69 percent of survey respondents said they often purchase products in packaging that can be recycled, up from 12 percent five years ago. | 12% | 69% |
| **Reducing the Number of Bags Used on Shopping Trips**<br>More than 60 percent of those surveyed say they cut back on the shopping bags they use, while only 19 percent said they did so in 1990. | 19% | 60% |
| **Reusing and Recycling Plastic Bags**<br>Reuse of plastic bags at home has nearly doubled, up from 46 percent in 1990 to over 88 percent today. And more than 77 percent of those surveyed say they currently recycle their plastic grocery bags. | 46% | 88% |

### How does *your* shopping stack up?

With more choices than ever in product packaging and recycling options, it's easy to get in the habit of shopping environmentally.

**For more information on plastic bag recycling, contact:**

The Plastic Bag Information Clearinghouse
1817 E. Carson Street • Pittsburgh, PA 15203 • 1-800-438-5856
e-mail: pbainfo@aol.com • URL: http://www.plasticbag.com

BEST COPY AVAILABLE

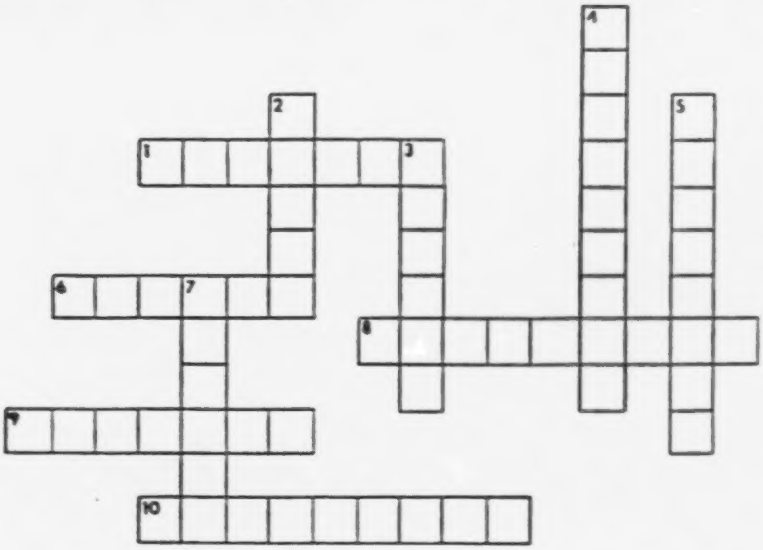
## 2. PLASTICS

### ACROSS

1. A molecule, usually a large one, made of many identical atom groups joined end to end.
6. A plastic used in cooking utensils, with "no-stick" properties.
8. _____ is used in making piano keys and photographic film.
9. A person who creates plastics in the lab.
10. Plastics are made from _____.

### DOWN

2. A tough flexible plastic used in clothing.
3. Molecules in _____ join together in a zigzag chain.
4. Teflon is resistant to nearly all _____, therefore it is used on containers for acids.
5. Some telephones are made of this polymer because it can be made to "set" in a hard rigid mass.
7. Transparent glasslike plastic. Also, a brand of paint.



NAME________________________

A S Y N D I O T A C T I C B C T H G I E W R A L U C E L O M
N G H L I T H O G R A D E Z I R E M Y L O P E R P N Z X X O
O C R Y S T A L X W G N H C C I M N N P U I H L C A W H D R
P O E M T L A D L E S B M E D I U M D E N S I T Y P W I T P
T N G S I L K Y O A T R Z Y X W E S T T H N G P C T P G O H
H D R P L A S T I C I Z E R P A R A F F I N H R G H Y H W O
A E I A A Q G S T Y R E N E H X N J R M O T I O N A M D E L
E N N T T U E T H Y L E N E O B Z E C A R D M O N O M E R O
Q S D Z E O L D M E L D G S T E E L T O E S P E O N E N B G
Z A S O L U B I L I T Y O D E W W A S T E W A T E R T S O Y
R T W E C O L D F L O W G Y L K A I S O T A C T I C A I T C
U I F G H O A E R T Y U G H D I S T I L L A T I O N L T T O
B O A D P F T G H J I K L N B V T V C M X Z B C D F L Y O N
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E F F L A T C L A D D I T I V E S L I N K O N Y Y C E T O A
V V Y E S N M L K S R E C Y C L E Y Z G E R G S E R S L R T
O I S O P R O P Y L L C A R B O N M F P T P P T L O W P N I
L S D D H G Y V P L E H H T E E T E I O O H O V I S E V N O
A C C K A F J C R O T C A E R P O R B I N O I O D S U P O N
T O P O L Y V I N Y L C H L O R I D E N E U N O P L U L I P
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Z I L K E E M A R F O E M I N E R A L O I L L A I N H S U L
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T Y E B E K Q U E N C H I N G J L E P K C I K F M E L I L K
I Y T N I M F D S A E X T R U S I O N L Z O I I I D T C O T
O A S T L F A N T I O X I D A N T S J E X L L L N O G K P L
N P O L Y P R O P Y L E N E S F I L M E L N L A D O M I B T

ADDITIVES
AMORPHOUS
ANTIOXIDANTS
ASPHALT
ASPHALTENE
ATACTIC
ATMOSPHERE
BIMODAL
BOILING POINT
CARBON
CATALYST
COLD FLOW
CONDENSATION
CROSSLINKED
CRYSTAL
DEVOLATILIZATION
DISTILLATION
ETHYLENE
EXTRUSION
FIBER
FILM
FLUFF
FRC
GEL

GOGGLES
GPC
HEXANE
HIGH DENSITY
HIGH IMPACT
INHIBITORS
ISOPROPYL
ISOTACTIC
LANDFILL
LINEAR LOW DENSITY
LITHOGRADE
MEDIUM DENSITY
MELTING POINT
METALLOCENES
MINERAL OIL
MOLECULAR WEIGHT
MONOMER
MORPHOLOGY
NAPTHA
PARAFFIN
PELLETS
PET
PLASTIC
PLASTICIZER

POLLUTION
POLYETHYLENETEREPHTHALATE
POLYMER
POLYPROPYLENE
POLYVINYLCHLORIDE
PREPOLYMERIZE
PROPYLENE
PVC
QUENCHING
REACTOR
RECYCLE
REGRIND
RUBBER
SOLUBILITY
STEEL TOES
STYRENE
SYNDIOTACTIC
TOWER BOTTOMS
VISCOSITY
VULCANIZE
WASTE
WASTE WATER
WAX

NAME______________________

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| P | O | E | M | T | L | A | D | L | E | S | B | M | E | D | I | U | M | D | E | N | S | I | T | Y | P | W | I | T | P |
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| E | N | N | T | T | U | E | T | H | Y | L | E | N | E | O | B | Z | E | C | A | R | D | M | O | N | O | M | E | R | O |
| Q | S | D | Z | E | O | L | D | M | E | L | D | G | S | T | E | E | L | T | O | E | S | P | E | O | N | E | N | B | G |
| Z | A | S | O | L | U | B | I | L | I | T | Y | O | D | E | W | W | A | S | T | E | W | A | T | E | R | T | S | O | Y |
| R | T | W | E | C | O | L | D | F | L | O | W | G | Y | L | K | A | I | S | O | T | A | C | T | I | C | A | I | T | C |
| U | I | F | G | H | O | A | E | R | T | Y | U | G | H | D | I | S | T | I | L | L | A | T | I | O | N | L | T | T | O |
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| B | N | S | E | P | L | A | S | T | C | I | H | E | X | A | N | E | N | E | E | P | O | O | A | K | M | O | O | M | D |
| E | A | R | N | B | A | C | O | R | N | G | O | S | L | I | M | E | C | O | L | O | R | I | T | A | E | C | A | S | E |
| R | P | O | L | Y | E | T | H | Y | L | E | N | E | T | E | R | E | P | H | T | H | A | L | A | T | E | E | P | A | N |
| D | P | L | I | N | H | I | B | I | T | O | R | S | O | F | Y | M | O | G | I | B | M | I | L | E | T | N | Y | C | S |
| E | F | F | L | A | T | C | L | A | D | D | I | T | I | V | E | S | L | I | N | K | O | N | Y | Y | C | E | T | O | A |
| V | V | Y | E | S | N | M | L | K | S | R | E | C | Y | C | L | E | Y | Z | G | E | R | G | S | E | R | S | L | R | T |
| O | I | S | O | P | R | O | P | Y | L | L | C | A | R | B | O | N | M | F | P | T | P | P | T | L | O | W | P | N | I |
| L | S | D | D | H | G | Y | V | P | L | E | H | H | T | E | E | T | E | I | O | O | H | O | V | I | S | E | V | N | O |
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ADDITIVES
AMORPHOUS
ANTIOXIDANTS
ASPHALT
ASPHALTENE
ATACTIC
ATMOSPHERE
BIMODAL
BOILING POINT
CARBON
CATALYST
COLD FLOW
CONDENSATION
CROSSLINKED
CRYSTAL
DEVOLATILIZATION
DISTILLATION
ETHYLENE
EXTRUSION
FIBER
FILM
FLUFF
FRC
GEL

GOGGLES
GPC
HEXANE
HIGH DENSITY
HIGH IMPACT
INHIBITORS
ISOPROPYL
ISOTACTIC
LANDFILL
LINEAR LOW DENSITY
LITHOGRADE
MEDIUM DENSITY
MELTING POINT
METALLOCENES
MINERAL OIL
MOLECULAR WEIGHT
MONOMER
MORPHOLOGY
NAPTHA
PARAFFIN
PELLETS
PET
PLASTIC
PLASTICIZER

POLLUTION
POLYETHYLENETEREPHTHALATE
POLYMER
POLYPROPYLENE
POLYVINYLCHLORIDE
PREPOLYMERIZE
PROPYLENE
PVC
QUENCHING
REACTOR
RECYCLE
REGRIND
RUBBER
SOLUBILITY
STEEL TOES
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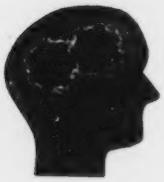
SYNDIOTACTIC
TOWER BOTTOMS
VISCOSITY
VULCANIZE
WASTE
WASTE WATER
WAX

# Use Your



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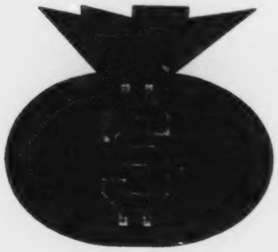
# Lose Your



## An Exercise in Deductive Reasoning and Industrial Success

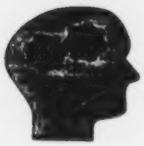
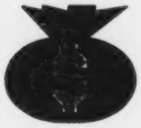
### *Use Your Mind or Lose Your Money*

***Objective:*** Students will use their critical thinking and problem solving skills to predict the each number in a sequence. Cooperative learning and delegation skills will also be practiced as students interact to determine which choices will enable them to make the best use of their money.

***Materials:***
1. Currency
2. Net Profit Sheet
3. Background and Rules Sheet

## Teacher Notes

1. Make copies of currency , cut currency into individual pieces and put into groups of $10,000.00 each, place Group # on each packet of " operating capital."
2. Determine the number of groups desired per class ( 3-4 students per group is a suggested number), assign students to a numbered group , and give each group their "operating capital" packet.
3. Determine the number sequence ( or sequences, if you want the game to be truly challenging for ALL class periods.) For example: 1,6,11,16…( adding 5 to each previous # ), or 36,49,64, 81 …. ( number multiplied by itself.)
4. Instruct each group to select a spokesperson to inform the CEO of the team's decisions concerning the appropriation of their funds, or to obtain a loan.

*Use Your*  *or Lose Your* 

The object of the game, as in most of life's games, is to outwit your competitors and end up with the most money.

Your Company owns a large polypropylene plant, whose profits have been less than satisfactory. The Board of Directors has determined that the technology presently used must be updated or modified in order to increase profits, and thus keep the plant operating.

A team of engineers believes it has developed technology ( represented by the correct number sequence) that will be successful and profitable. A problem in the sequencing, however could prove disastrous.
Your mission, should you decide to accept it, is to try to determine the correct sequence of numbers which would then enable you to implement the new technology , thus keeping the plant running and making you wildly rich.

***Rules of the Game***

1. Each group will be given $10,000 operating capital and the first number in the sequence.

2. The game will be composed of ten rounds. In each round you may allocate your funds in the following manner.

   a.) For $1000.00 you can do Research and Development and obtain the next number in the sequence.

   b.) For $2000.00 you may run a Pilot Plant study, were you must predict the next number in the sequence.

   If your prediction is correct your profit is $10,000.00
   If your prediction is incorrect:

   by 1 ---- A pump failure has occurred, costing you an additional $1000.00

   by 2 ---- Your raw materials were contaminated, and it will cost an additional $3000.00 to purge the system

   by 3 ---- An air leak oxidized your product, rendering it useless Since you cannot sell the product, you have lost an additional $7000.00.

by more than 3 ---- The workers have gone on strike. New workers had to be hired. The downtime cost plus the cost of training the new employees requires an additional $15000.00.

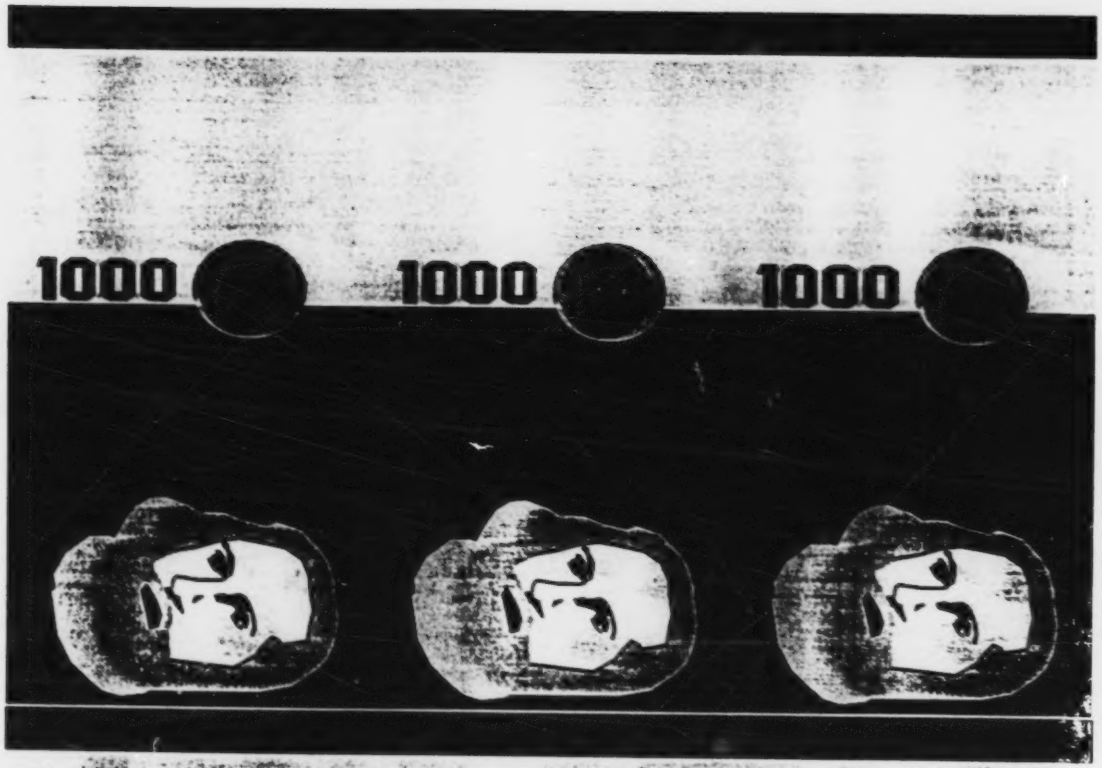
c.) For $5000.00 you can do a full scale plant run. in which you must predict the next correct number in the sequence.

If your prediction is correct. your profit is $30,000.00

If your prediction is incorrect, a runaway reaction has occurred. The entire reactor overheats, and a total plant shut down costs you $60,000.00

The company with the greatest financial gain at the end of the first quarter( 35 min.) will win the game and be given a BONUS !

**** In the event that you've been ill advised, and your capital is depleted, loans are available from the CEO of your competitor company in increments of $10,000.00 at 10% interest.****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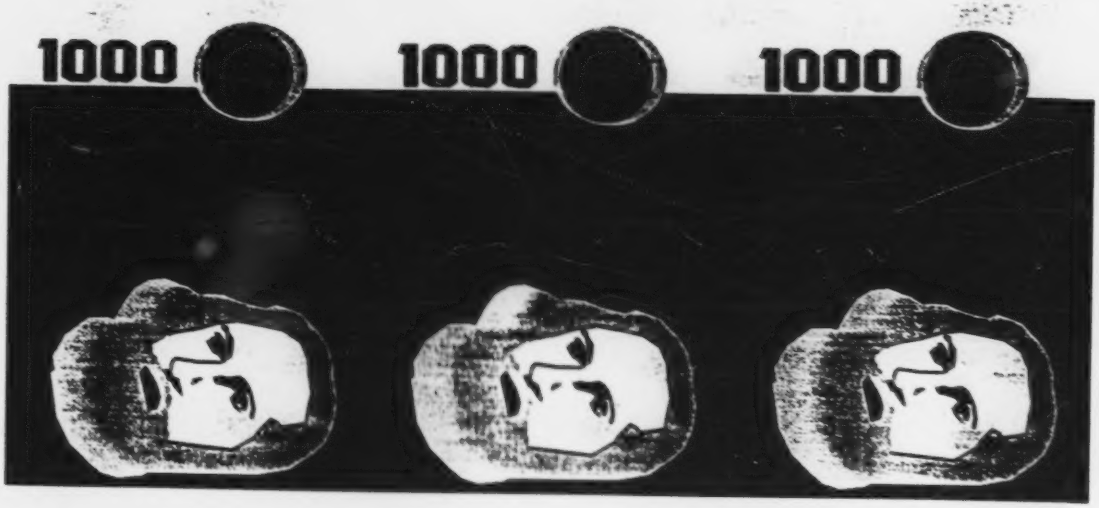
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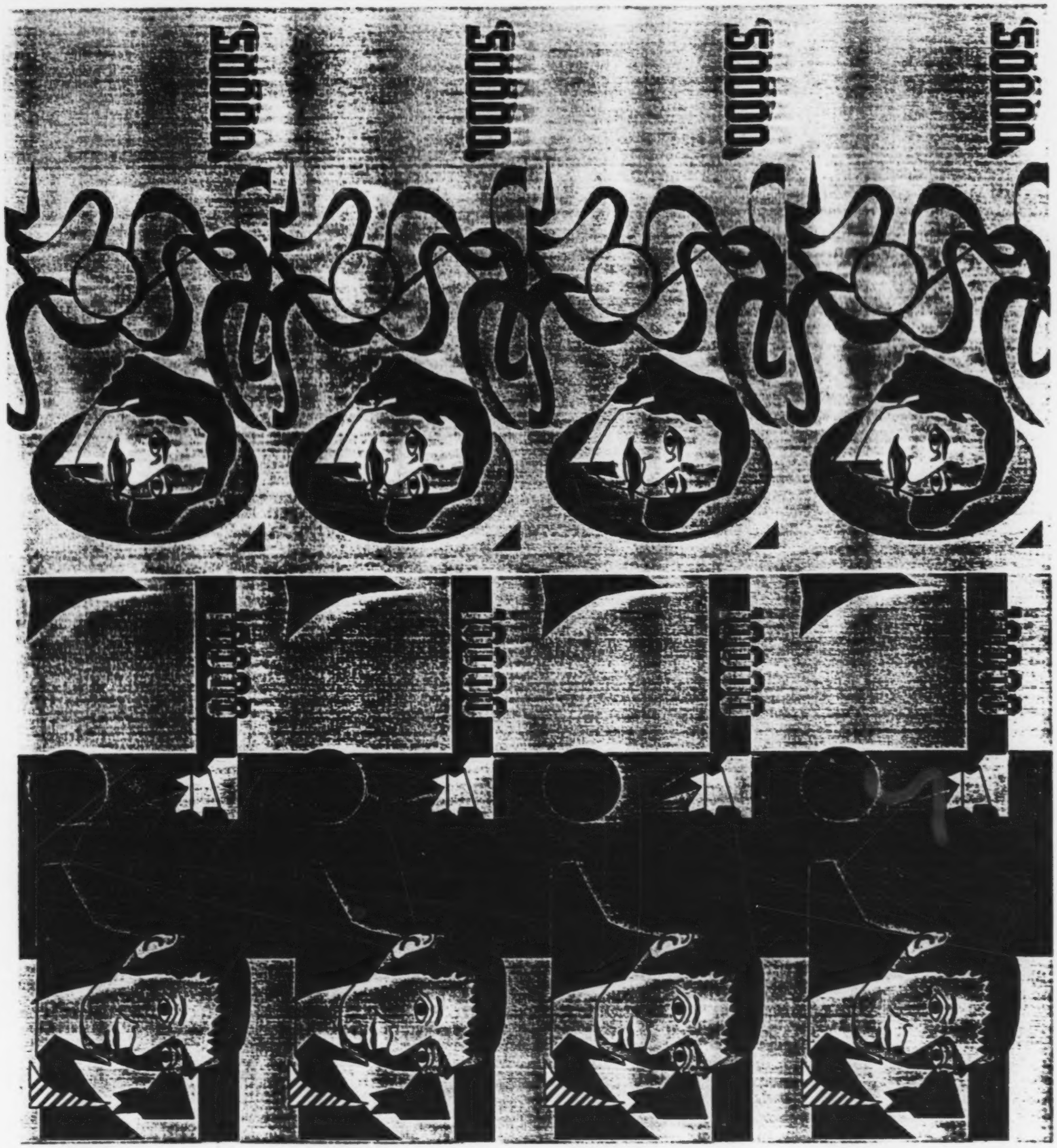
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# *Net Profit Sheet*

***Group Number*** ______

| Prediction | Actual # | Prediction off by | Profit | Loss | Loan + Interest | Total |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
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## *Wrap it Up*

A Film Line Case Study

Teacher Notes

***Objective:*** Utilizing comprehension and retention skills, students will demonstrate ability to differentiate between factual information and personal interpretation ( inference.)

***Materials:*** 1. Wrap it Up - A Film Line Case Study
2. True / False Question sheet per student and per group

***Procedure:*** 1. Pass out Case Study sheet to each student and allow approximately one to two minutes to read the case study.

2. Take up Case Study sheet and distribute the True / Fault Question.

3. After students have answered all the questions individually, place the students into groups of three or four, and have them fill out another True /Fault Question sheet as a group.

****You may want to make a transparency of the answer sheet, and once again answer each question as a class. This will enable each group to explain the reasoning they used to come to their conclusions.

## Film Line : Case Study

The film line was in operation. The technician was checking the continuous pellet feed. Joe started the film on the roller. The film was tested for the presence of undesirable gels. Twenty gels were found on the film . Test results were then reported back to the supervisor.

1. Joe started the film line. T F

2. The technician was a man. T F

3. The technician's name is Joe. T F

4. Joe tested the film for undesirable gels . T F

5. The film contained gels. T F

6. The technician stopped the film line once the sample was obtained. T F

7. The film was made from a polymer. T F

8. Gels were found on the film at a ratio of 20 per foot. T F

9. The film was rejected because of the gels. T F

10. Joe reported the test results to the supervisor. T F

11. The story contains a series of events in which only three persons are referred to, Joe, the technician and the supervisor. T F

## *Are You Out Of Control?*

***Objective:*** Students will demonstrate the ability to graph data, determine average values, and use formulas to calculate Upper and Lower Control Limits. Students will interpret and evaluate data to determine the stability of a process.

***Materials:*** 1. Background and Procedures sheet.
2. Data tables
3. Graph sheets

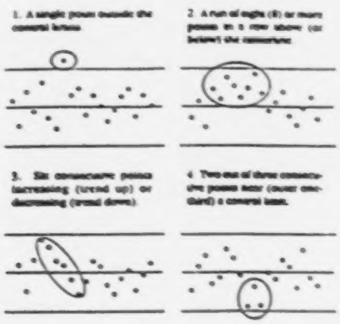
# Are You Out of Control?

A ***control chart*** is a statistical tool used to distinguish between variations in a process due to ***common causes***, those causes that are inherent in the process over time, affect everyone working in the process, and affect all outcomes of the process, and variations due to ***special causes,*** those causes that are not part of the process all the time or do not affect everyone, but arise because of special circumstances.

A process, which has only common causes affecting the outcomes, is called a ***stable process*** or one which is in a state of statistical control. A stable process implies only that the variation is predictable within bounds. A process, whose outcomes are affected by both common and special causes, is called an ***unstable process.*** For an unstable process, the variation from one time period to the next is unpredictable. As special causes are identified and removed, the process becomes stable.

To determine a *special cause* (an out of control system), one of the following criteria must be met.

1. A single point is outside of either the UCL or LCL..
2. A run of eight or more points in a row above or below the center line (*mean*).
3. Six consecutive points increasing ( trend up) or decreasing ( trend down).
4. Two out of three consecutive points near (outer one third) a control limit.



The Maintenance Department in a large polypropylene film production plant began a quality improvement program. Initial efforts focused on improving processes to increase production of a quality product. After obtaining and analyzing data for one month , the three major problem areas targeted were, *stockouts, parts breaking, and performance failures.*

The data listed on the following sheet was obtained during the next month.

***Procedure:*** For each set of data

1. Construct a line graph of the data
2. Calculate the MR ( moving range) [ Formula given in table]
3. Calculate X average ( the mean ) [ Sum of all the data divided by the number of data points]
4. Calculate the MR average [ Sum of all the MR values divided by the number of MR values.]
5. Calculate the UCL ( Upper Control Limit) [ Formula given in table.]
6. Calculate the LCL ( Lower Control Limit) [ Formula given in table.]

***Conclusion:***

1. Were any special cause situations present on your graph?
2. Give two reasons why your graph did or did not have a special cause situation.
3. What is the name given to factors that affect the outcome of an experiment?
4. Are there any manipulated variables present?
5. Why are days plotted on the x axis ?
6. Why are the repairs/types of repairs plotted on the y axis?

| Day | # of repairs | MR |
|---|---|---|
| 1 | 210 | |
| 2 | 204 | 6 |
| 3 | 220 | 16 |
| 4 | 223 | 3 |
| 5 | 200 | 23 |
| 6 | 120 | 80 |
| 7 | 230 | 110 |
| 8 | 181 | 49 |
| 9 | 196 | 15 |
| 10 | 224 | 28 |
| 11 | 230 | 6 |
| 12 | 105 | 125 |
| 13 | 227 | 122 |
| 14 | 198 | 29 |
| 15 | 250 | 52 |
| 16 | 275 | 25 |
| 17 | 270 | 5 |
| 18 | 96 | 174 |
| 19 | 218 | 122 |
| 20 | 188 | 30 |
| 21 | 205 | 17 |
| 22 | 230 | 25 |
| 23 | 180 | 50 |
| 24 | 110 | 70 |
| 25 | 210 | 100 |
| X avg | 200 | |
| MR avg | 53.4 | |
| UCL | 342 | |
| LCL | 58 | |

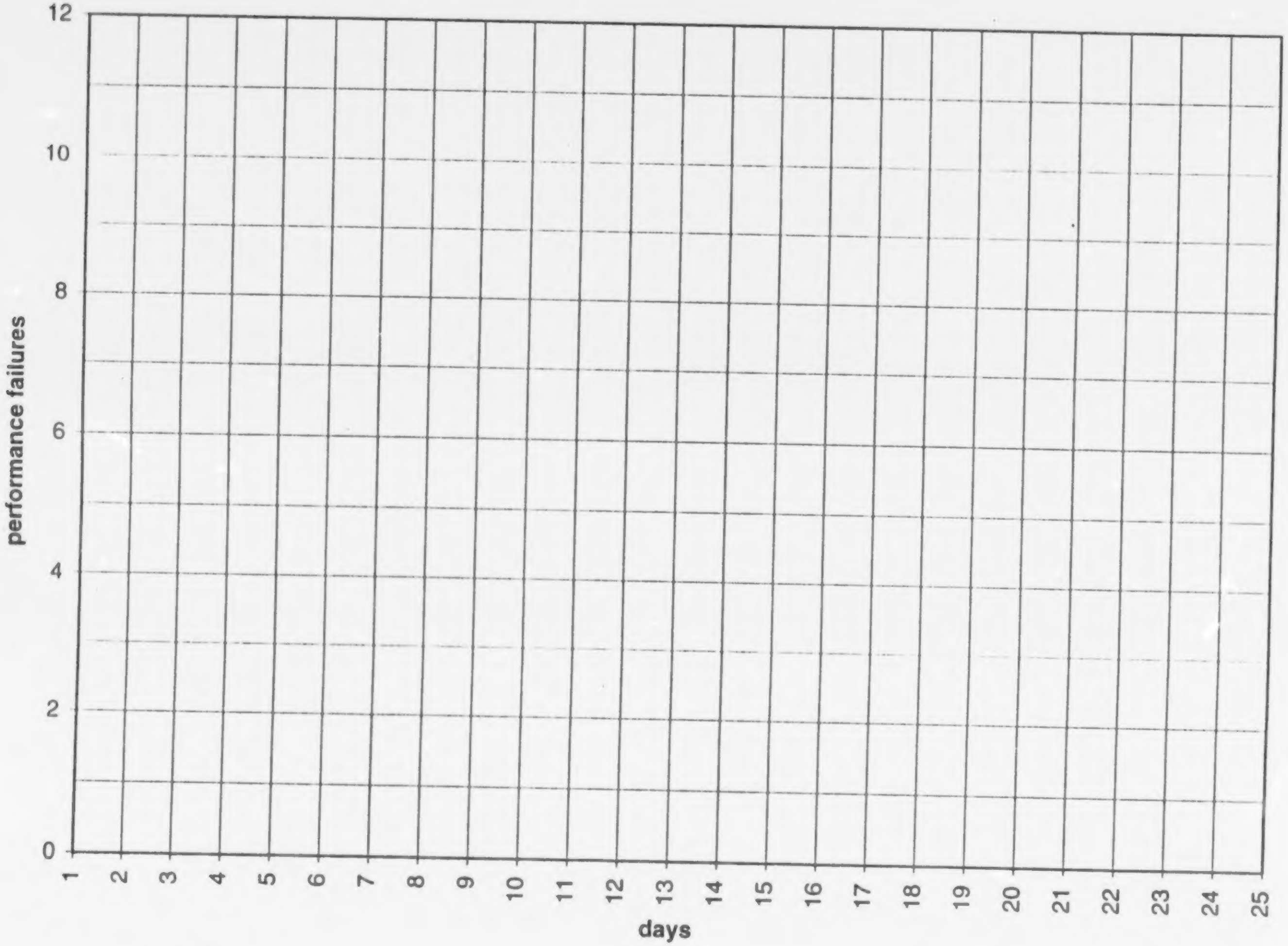
| Day | stockouts | MR |
|---|---|---|
| 1 | 5 | |
| 2 | 7 | 2 |
| 3 | 3 | 4 |
| 4 | 11 | 8 |
| 5 | 0 | 11 |
| 6 | 2 | 2 |
| 7 | 9 | 7 |
| 8 | 1 | 8 |
| 9 | 4 | 3 |
| 10 | 12 | 8 |
| 11 | 8 | 4 |
| 12 | 5 | 3 |
| 13 | 2 | 3 |
| 14 | 0 | 2 |
| 15 | 3 | 3 |
| 16 | 7 | 4 |
| 17 | 9 | 2 |
| 18 | 2 | 7 |
| 19 | 6 | 4 |
| 20 | 2 | 4 |
| 21 | 6 | 4 |
| 22 | 8 | 2 |
| 23 | 3 | 5 |
| 24 | 5 | 2 |
| 25 | 5 | 0 |
| X avg | 5 | |
| MR avg | 4.3 | |
| UCL | 16 | |
| LCL | -6 | |

| Day | parts breaking | MR |
|---|---|---|
| 1 | 10 | |
| 2 | 18 | 8 |
| 3 | 11 | 7 |
| 4 | 8 | 3 |
| 5 | 14 | 6 |
| 6 | 8 | 6 |
| 7 | 21 | 13 |
| 8 | 16 | 5 |
| 9 | 12 | 4 |
| 10 | 18 | 6 |
| 11 | 10 | 8 |
| 12 | 8 | 2 |
| 13 | 36 | 28 |
| 14 | 27 | 9 |
| 15 | 22 | 5 |
| 16 | 35 | 13 |
| 17 | 40 | 5 |
| 18 | 5 | 35 |
| 19 | 11 | 6 |
| 20 | 9 | 2 |
| 21 | 5 | 4 |
| 22 | 19 | 14 |
| 23 | 20 | 1 |
| 24 | 9 | 11 |
| 25 | 8 | 1 |
| X avg | 16 | |
| MR avg | 8.4 | |
| UCL | 38 | |

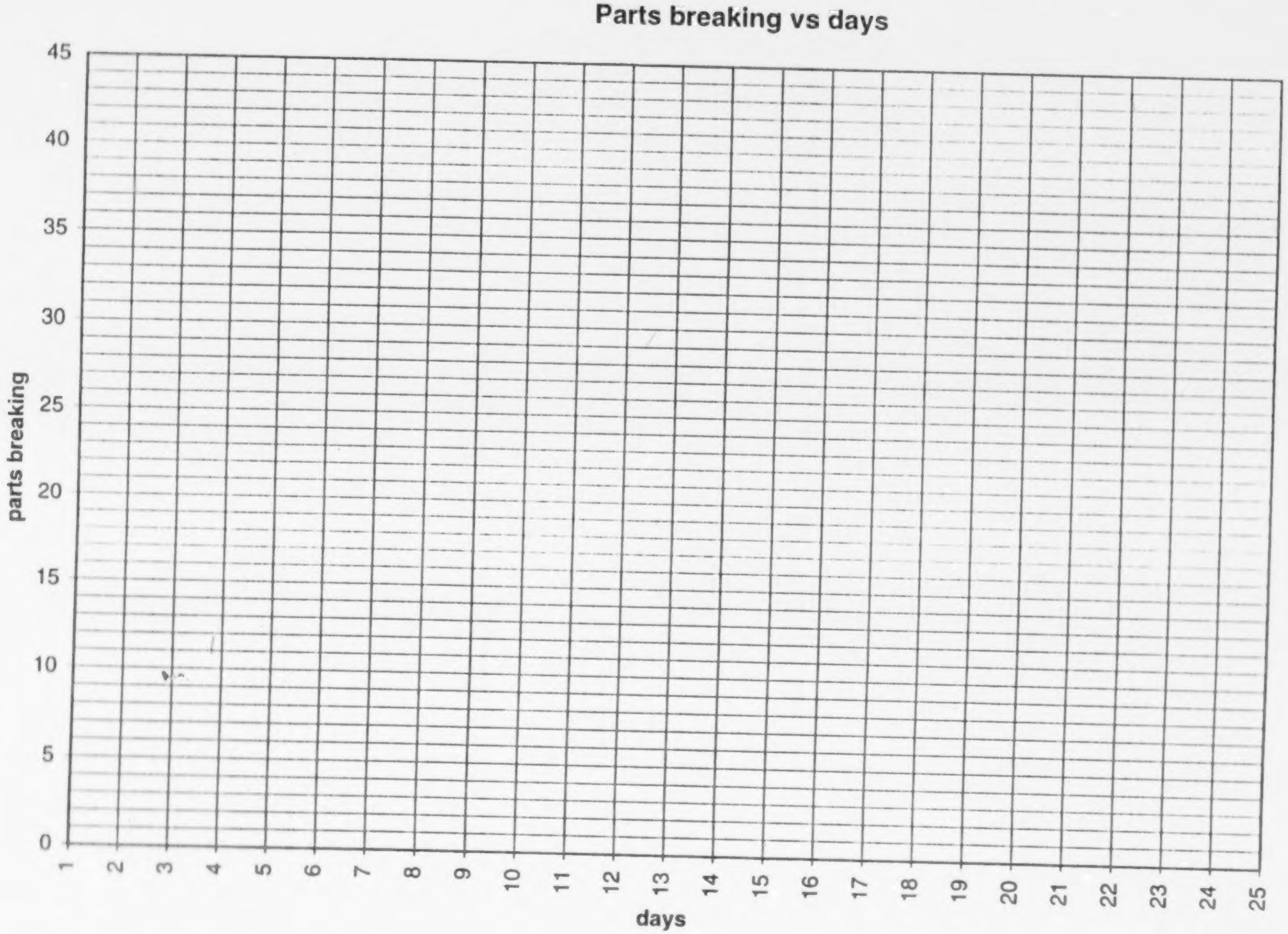
| Day | performance failures | MR |
|---|---|---|
| 1 | 2 | |
| 2 | 3 | 1 |
| 3 | 3 | 0 |
| 4 | 5 | 2 |
| 5 | 3 | 2 |
| 6 | 0 | 3 |
| 7 | 0 | 0 |
| 8 | 7 | 7 |
| 9 | 1 | 6 |
| 10 | 3 | 2 |
| 11 | 7 | 4 |
| 12 | 2 | 5 |
| 13 | 0 | 2 |
| 14 | 2 | 2 |
| 15 | 4 | 2 |
| 16 | 4 | 0 |
| 17 | 1 | 3 |
| 18 | 0 | 1 |
| 19 | 6 | 6 |
| 20 | 3 | 3 |
| 21 | 1 | 2 |
| 22 | 5 | 4 |
| 23 | 4 | 1 |
| 24 | 3 | 1 |
| 25 | 6 | 3 |
| X avg | 3 | |
| MR avg | 2.6 | |
| UCL | 10 | |

| Day | performance failures | MR (absolute value of Day1-Day2, Day 2-Day 3, etc.) |
|---|---|---|
| 1 | 2 | |
| 2 | 3 | |
| 3 | 3 | |
| 4 | 5 | |
| 5 | 3 | |
| 6 | 0 | |
| 7 | 0 | |
| 8 | 7 | |
| 9 | 1 | |
| 10 | 3 | |
| 11 | 7 | |
| 12 | 2 | |
| 13 | 0 | |
| 14 | 2 | |
| 15 | 4 | |
| 16 | 4 | |
| 17 | 1 | |
| 18 | 0 | |
| 19 | 6 | |
| 20 | 3 | |
| 21 | 1 | |
| 22 | 5 | |
| 23 | 4 | |
| 24 | 3 | |
| 25 | 6 | |
| X avg | | |
| MR avg | | |
| UCL = Xavg + (2.66 x MRavg) | | |
| LCL = Xavg - (2.66 x MRavg) | | |

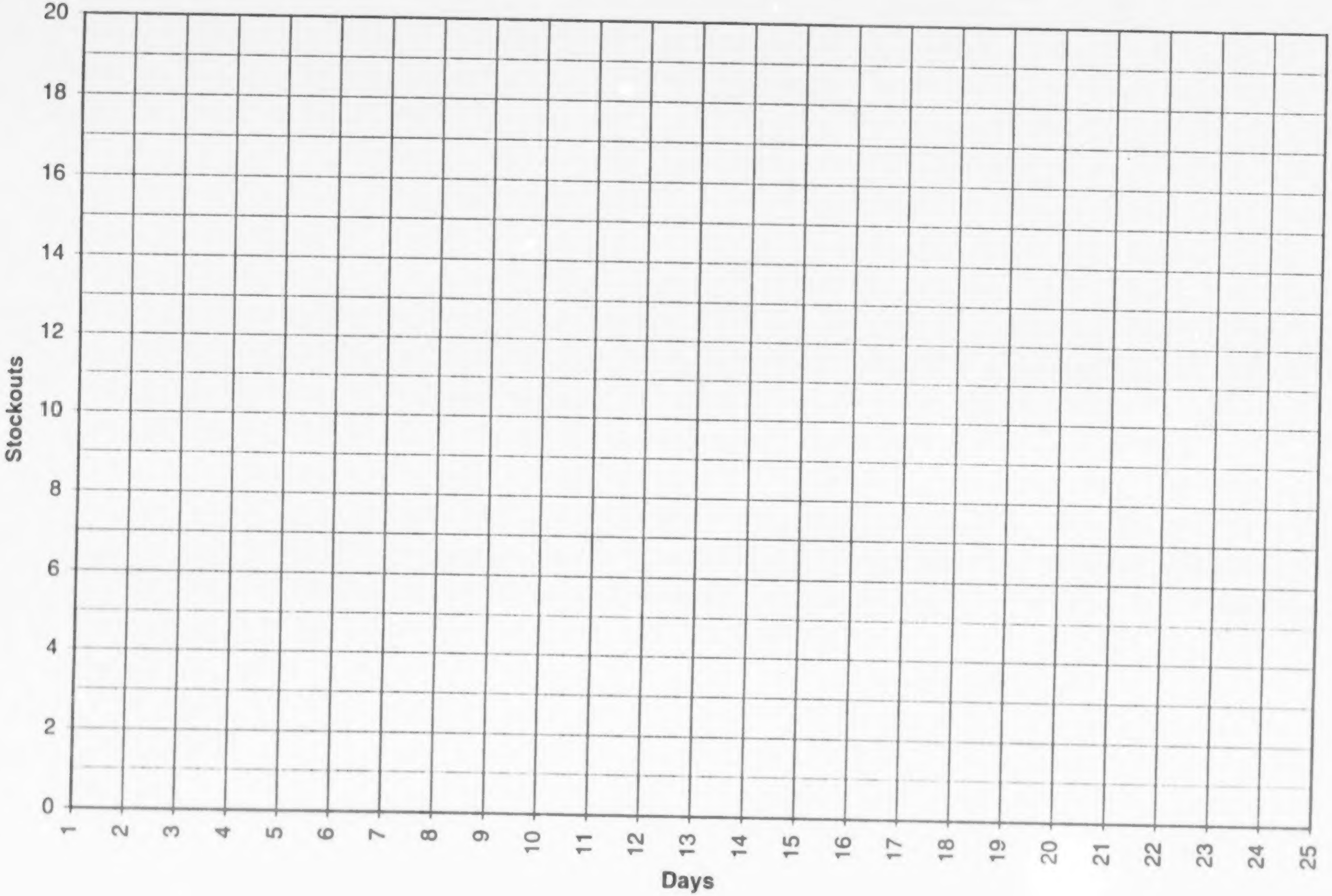
**Performance failure vs days**



| Day | parts breaking | MR (absolute value of Day1-Day2, Day 2-Day 3, etc.) |
|---|---|---|
| 1 | 10 | - |
| 2 | 18 | |
| 3 | 11 | |
| 4 | 8 | |
| 5 | 14 | |
| 6 | 8 | |
| 7 | 21 | |
| 8 | 16 | |
| 9 | 12 | |
| 10 | 18 | |
| 11 | 10 | |
| 12 | 8 | |
| 13 | 36 | |
| 14 | 27 | |
| 15 | 22 | |
| 16 | 35 | |
| 17 | 40 | |
| 18 | 5 | |
| 19 | 11 | |
| 20 | 9 | |
| 21 | 5 | |
| 22 | 19 | |
| 23 | 20 | |
| 24 | 9 | |
| 25 | 8 | |
| X avg | | |
| MR avg | | |
| UCL = Xavg + (2.66 x MRavg) | | |
| LCL = Xavg - (2.66 x MRavg) | | |

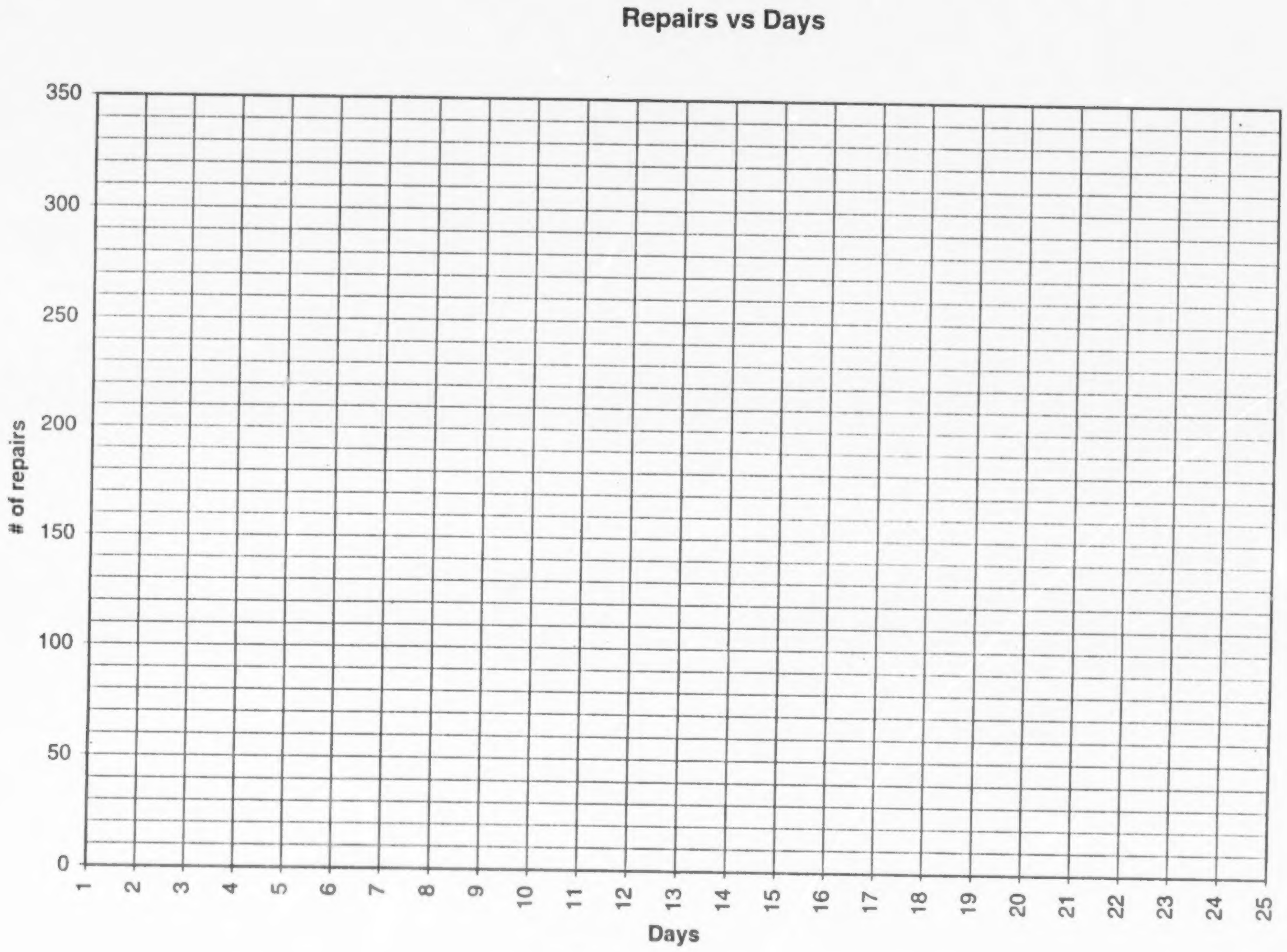

Parts breaking vs days
parts breaking
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
days

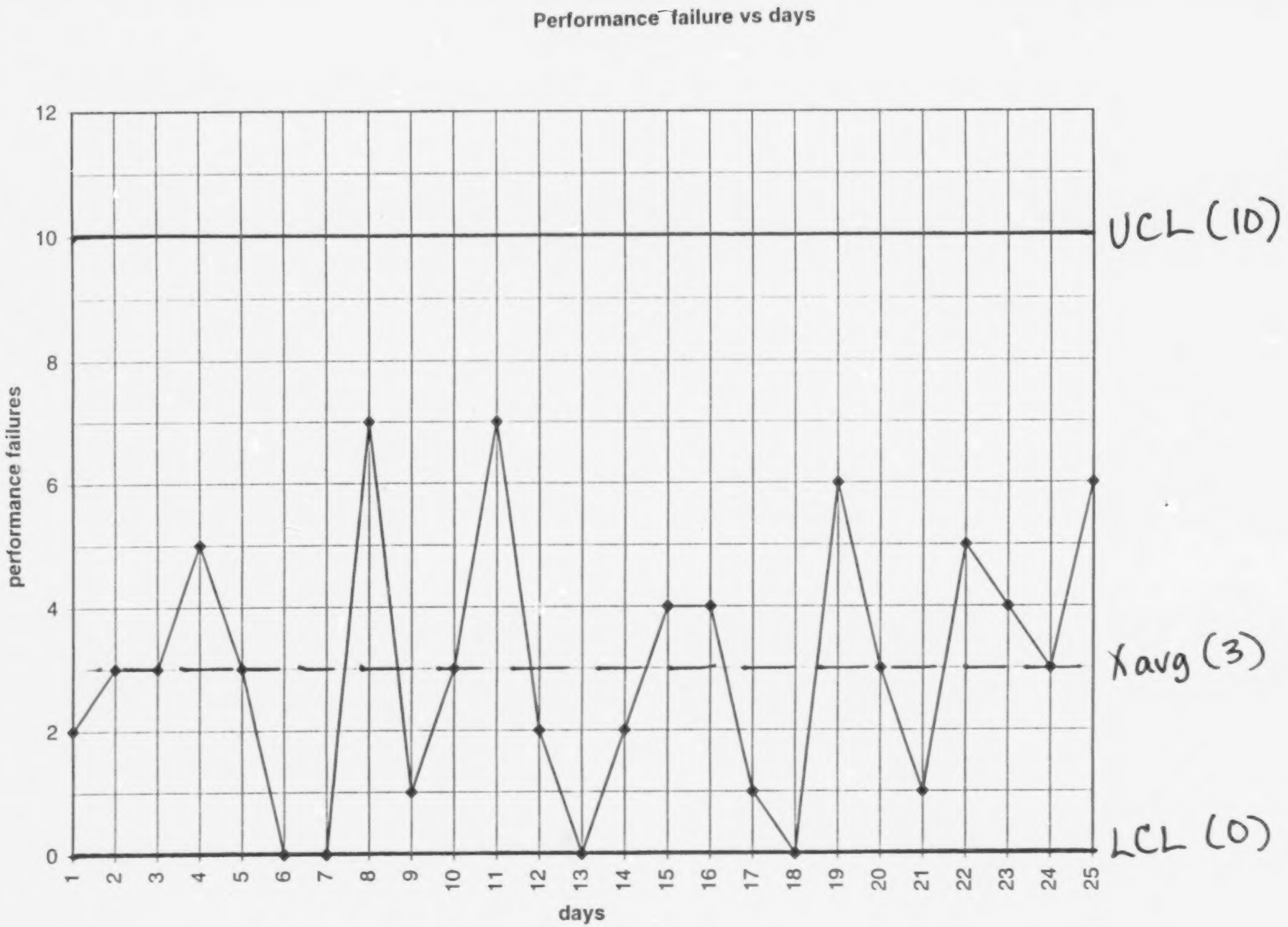
| Day | stockouts | MR (absolute value of Day1-Day2, Day 2-Day 3, etc.) |
|---|---|---|
| 1 | 5 | - |
| 2 | 7 | |
| 3 | 3 | |
| 4 | 11 | |
| 5 | 0 | |
| 6 | 2 | |
| 7 | 9 | |
| 8 | 1 | |
| 9 | 4 | |
| 10 | 12 | |
| 11 | 8 | |
| 12 | 5 | |
| 13 | 2 | |
| 14 | 0 | |
| 15 | 3 | |
| 16 | 7 | |
| 17 | 9 | |
| 18 | 2 | |
| 19 | 6 | |
| 20 | 2 | |
| 21 | 6 | |
| 22 | 8 | |
| 23 | 3 | |
| 24 | 5 | |
| 25 | 5 | |
| X avg | | |
| MR avg | | |
| UCL = Xavg + (2.66 x MRavg) | | |
| LCL = Xavg - (2.66 x MRavg) | | |



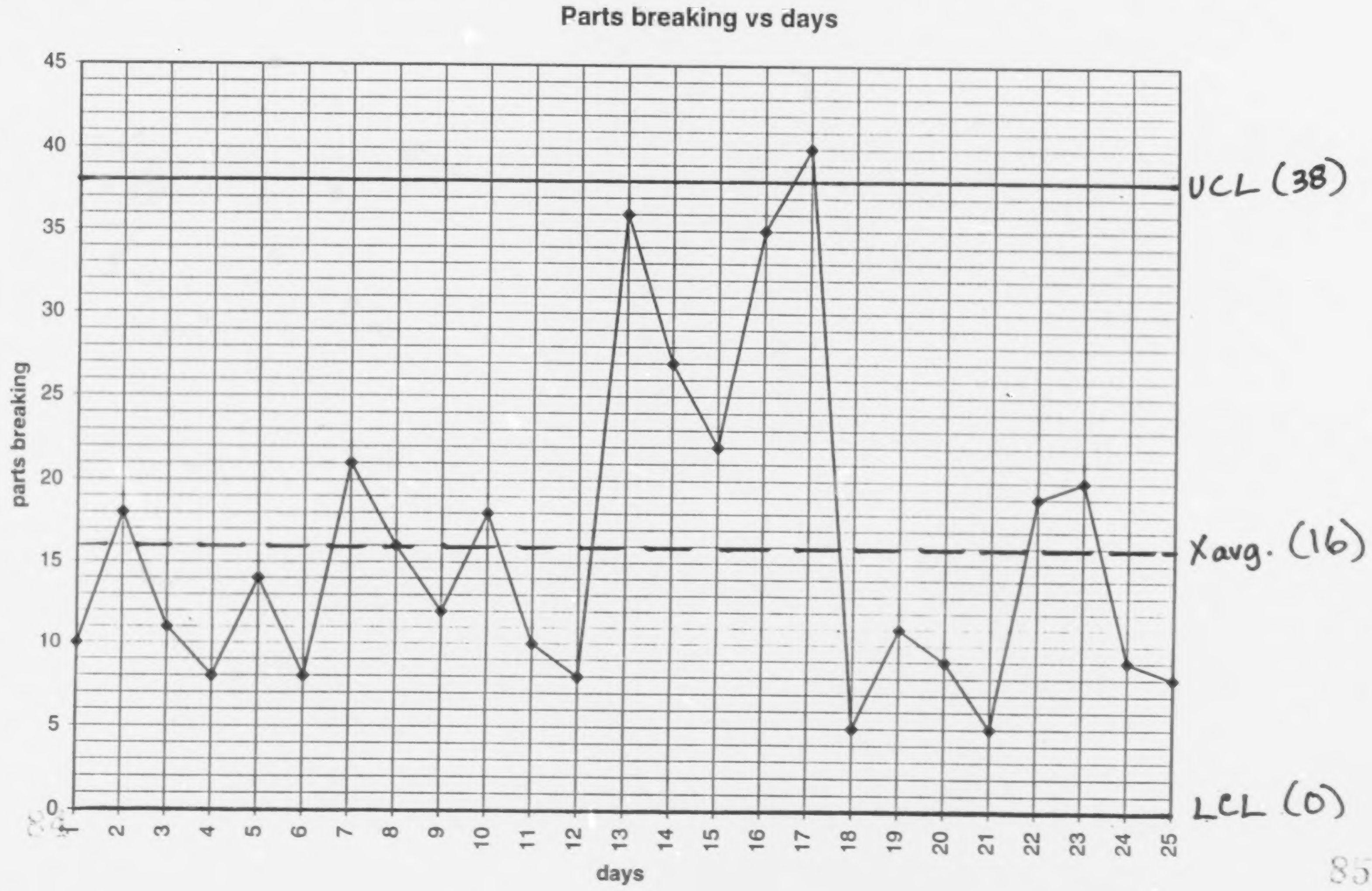
Stockouts vs Days

| Day | # of repairs | MR (absolute value of Day1-Day2, Day 2-Day 3, etc.) |
|---|---|---|
| 1 | 210 | - |
| 2 | 204 | |
| 3 | 220 | |
| 4 | 223 | |
| 5 | 200 | |
| 6 | 120 | |
| 7 | 230 | |
| 8 | 181 | |
| 9 | 196 | |
| 10 | 224 | |
| 11 | 230 | |
| 12 | 105 | |
| 13 | 227 | |
| 14 | 198 | |
| 15 | 250 | |
| 16 | 275 | |
| 17 | 270 | |
| 18 | 96 | |
| 19 | 218 | |
| 20 | 188 | |
| 21 | 205 | |
| 22 | 230 | |
| 23 | 180 | |
| 24 | 110 | |
| 25 | 210 | |
| X avg | | |
| MR avg | | |
| UCL = Xavg + (2.66 x MRavg) | | |
| LCL = Xavg - (2.66 x MRavg) | | |

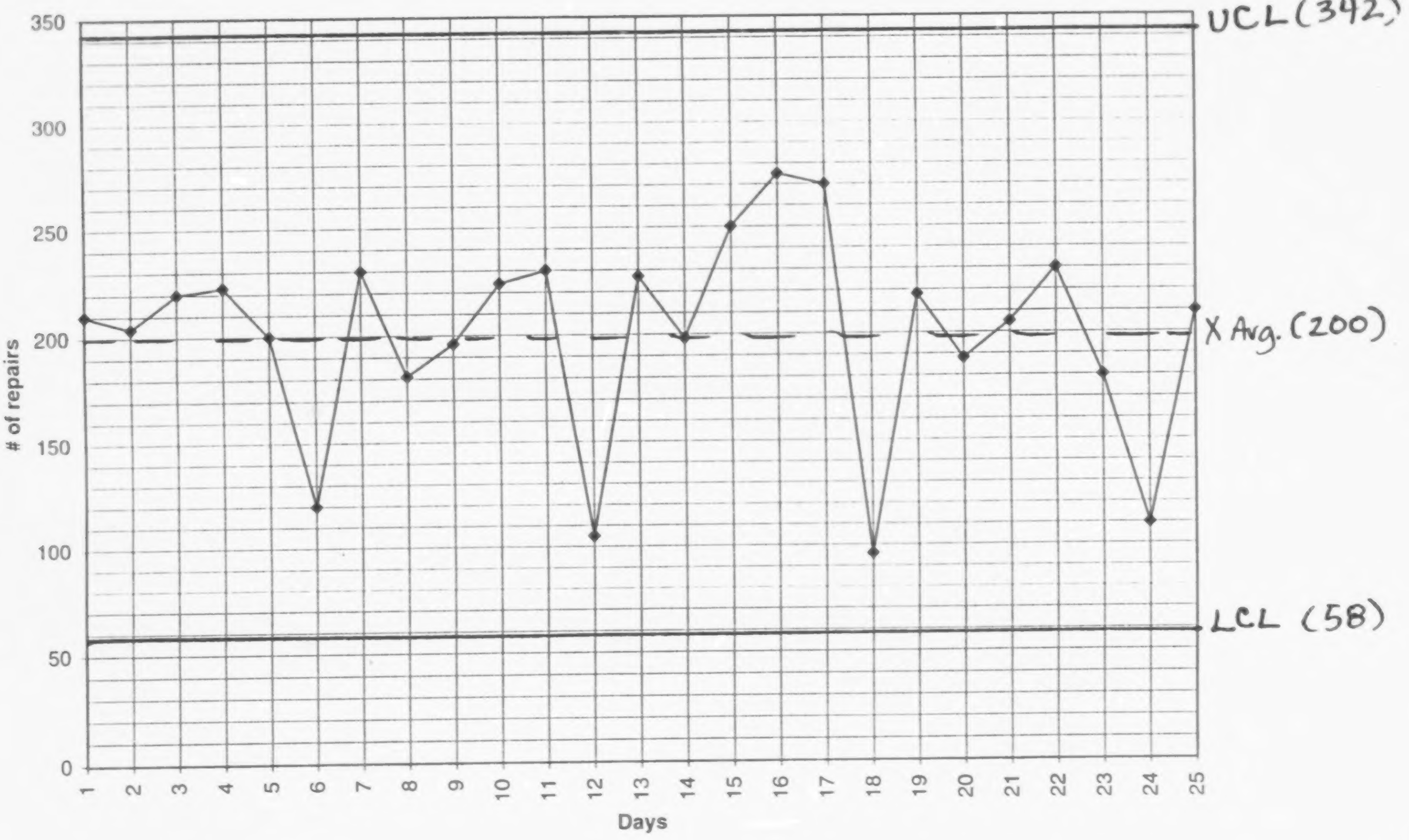

Repairs vs Days
# of repairs
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Days



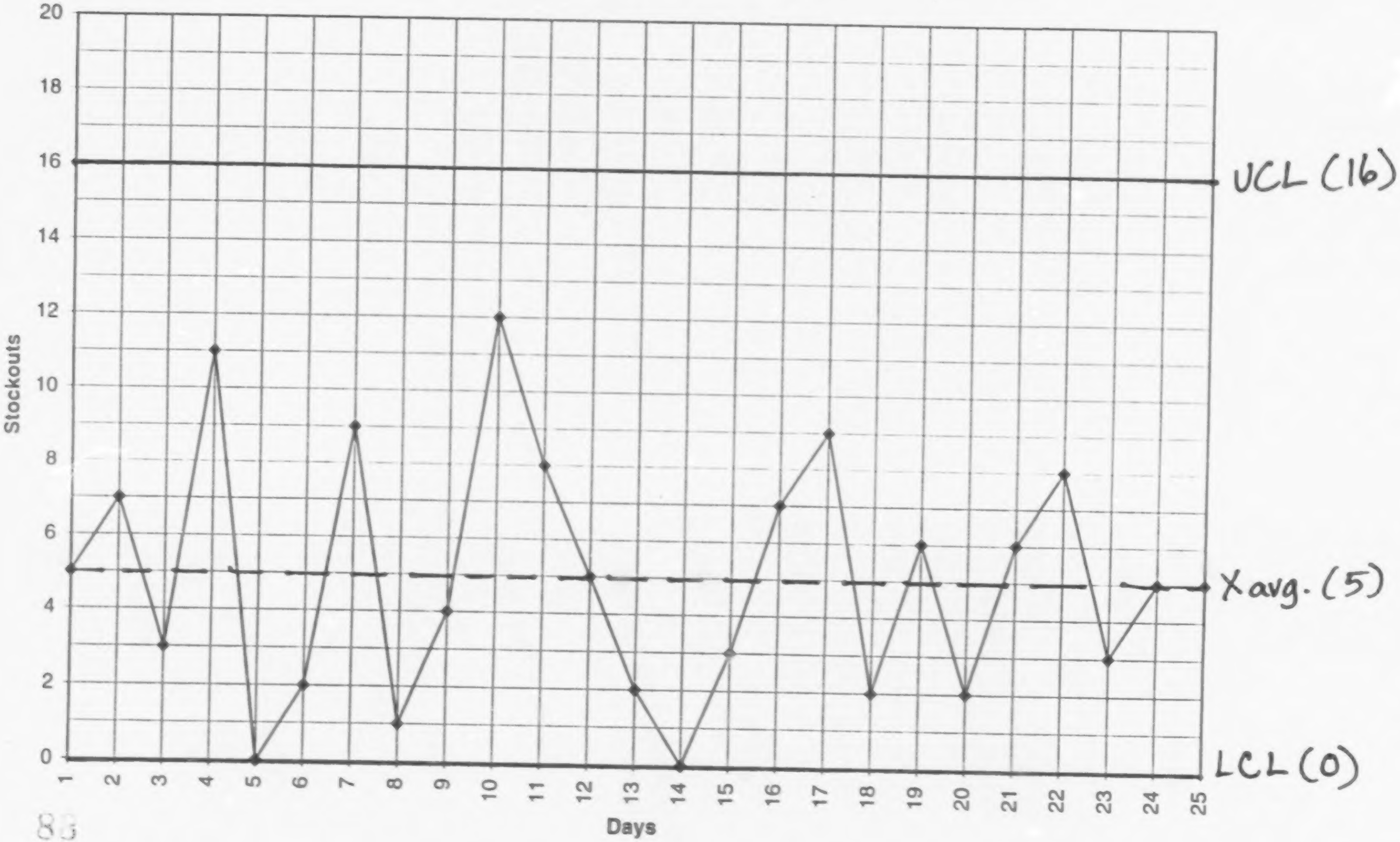
Performance failure vs days


Parts breaking vs days
parts breaking
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
days
UCL (38)
Xavg. (16)
LCL (0)

Repairs vs Days



Stockouts vs Days



# Norene Rose Flaherty
## Science
## J.L. Long Middle School, Dallas ISD

**Texas Utilities Electric, Dallas**
**Orlan Ihms, Mentor**

**Dallas USI Grant**
**Betty Fisher, Coordinator**

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# TTIP
# CURRICULUM IMPLEMENTATION PLAN
## Abstract

NAME: Norene Flaherty

INTERNSHIP: TUElectric
Orlan Ihms, Mentor

SCHOOL: J. L. Long Middle School
6116 Reiger, Dallas, Texas 75224
214-841-5270

PRIMARY SUBJECT: Composite Science - Science II

COMPONENTS: Program Overview - Energy Production and Use of Non-Renewable Fossil Fuels and Their Environmental Impact

COAL - Cycle of Lignite - Collecting Data From a Video Grouping/Assigning Grades/Tips
COAL - Surface Mining in a Suitcase
COAL - Testing Fly Ash in Concrete for Strength
ACID RAIN - Industrial Cleaners and How They Operate
ACID RAIN - Simulating Electrostatic Precipitators and Wet Scrubbers in the Classroom
WILDLIFE - Counting Texas Bald Eagles

SUMMARY: A global preparation based on Energy Production, Use, and Conservation of both Non-Renewable/Renewable resources reflecting responsible environmental impact by an energy company. Components are excerpts from broader units that include readings, other labs/activities and supportive materials. Additional units covering Electricity, Heat Transfer, Wetlands, The New Environmentalists are under construction. Also, units on renewable energy are near completion. Available in DISK and hardcopy.

MAIN RESEARCH SOURCES: (See Itemized list submitted)
Varied TU Employees and their areas of expertise
Edison Institute
Resources from the Internet
TUElectric Educational Materials
State of Texas Office of Air Quality
Texas Parks & Wildlife
Environmental Protection Agency

# THE CYCLE OF LIGNITE
# STUDENT ACTIVITY

There are many and varied uses for the video, The Cycle of Lignite within the curriculum. Following are some - you will probably think of many more based upon your own unique teaching style.

Materials
Video - The Cycle of Lignite - 19 minutes
Student list of 60 questions divided into six segments that include history, pre-planning for environmental impact, mining and reclamation, using coal to generate electricity, finding uses for coal byproducts and impact on the community.
Teacher Strategies and key
Surface Mining Suitcase Lab
Grading Sheet
Tips/Strategies

Research - collecting data
1. Lead into video by asking the question "Where Does Electricity Come from? Find out what students already know. Explain that they will see an example of a Texas company that produces electricity and also protects the environment as the process occurs.

Tell them that they will collect data that will assist in answering the question and make them more knowledgeable about Texas coal mining.

In a class of 30 students, give each student two questions. Make certain they are given at random from different categories. They could draw two numbers out of a "Genius Hat". Their responsibility is to then watch the video and write down the answers to their questions. They will share with the class. As they share, other students write down their answers and teacher can fill in more information and generate discussion. Students are told they may answer other questions as well but must be prepared to discuss those they are responsible for.

Post Video Suggestions
When all questions have been answered, follow with a Science/Art homework lab in which students must use their "research" material to

draw the Cycle of Lignite. This can be a multi-day assignment.

2. Divide students into teams and make them responsible for collecting data in one of the six areas of the video - they then must choose a method of exhibiting and reporting their data.

3. Teacher shows video but stops after each segment. Questions are discussed as a lead in for simulation labs on cleaning air, water and land available in other segments of the curriculum.

4. Divide students into teams and have them identify places and functions as outlined in the "Suitcase". Have students use lab sheet as a guide.

5. Divide your students again and have them use productive thinking to fill a paper with the many, varied and unusual careers found in the mining industry.

6. Divide your students into teams and using the resources above, ask them to solve the following problem:

You have been selected as a team to open and manage a new coal mine. Planning, as you have been told, is essential. Expand your ideas by

1. Developing a plan-Have them develop a graphic organizer
2. Discuss as a team what you've planned
3. Create a master list of materials you will need and
4. Steps you will take
5. Draw some conclusions about the challenges of modern mining

7. Use the following posters from the National Energy Foundation for more ideas - and for display in the classroom.

From the Mine to My Home
Coal
Coal Technology, The Future is Now

8. Use as display the TU poster, Electricity From Lignite Coal

Cycle of Lignite Video and Surface Mining Suitcase provided by Orlan Ihms, TU Electric, Educational Services

# THE CYCLE OF LIGNITE
# ENERGY AND THE ENVIRONMENT

## THE HISTORY OF COAL MINING IN TEXAS

1. This occurrence takes place in East Texas - home to ____________, farmland and lush pine ______________.

2. Each is a visible valuable ____________.

3. Beneath the land are invisible resources such as ___________, natural gas and _________.

4. The most plentiful type of coal in Texas is __________; it is soft and ______________ best used for generating electricity.

5. The history of coal in Texas starts in 1926 when it was first mined in Malakoff.

6. Soon after, __________ _______was found to be cheaper to burn as fuel for electricity so coal was no longer used.

7. The Sandow mine was opened in __________.

8. The Sandow mine did two important things. It trained key ______________and developed new ____________________.

9. Oil and gas prices rose sharply in _______________.

10. In _______ Big Brown Mining and Power and Plant was opened. It was the first modern plant in the state of Texas.

11. Mining lignite temporarily disturbs the natural cycles of _______, _________and _________.

## THE FIRST RULE OF INTELLIGENT TINKERING IS TO SAVE ALL THE PIECES, Aldo Leopold

## PLANNING THE ENVIRONMENT

12. TU decided to try planning that would disturb the land least - this made good ________________and ________________sense.

13. In the year _________a new environmental program began.

14. What type of educational background did the new Director have?
__________________________.

15. What did the company do to protect the environment?
_________________ ________ ______________________.

16. Could anyone predict what impact the mining of coal on the surrounding area would do to air, land and water? ____________

17. When did the company want to find the answer to the above question?
_______________________________________.

18. What was the first step in planning for protection of the environment? ________________________________________________

19. The studies and actual work to find out was done by
_________________________________.

20. Studies covered grasses, impact on trees and how quick animals _________land.

21. Dr. Frank Hom from Texas A & M University studied grasses and legumes and developed good winter ground cover to prevent soil erosion. He discovered that ________ ___________and __________ _________ were the best answers to the problem. This was a tremendous advantage to farmers and ranchers.

22. What was the major concern of the farmers and ranchers?

______________________________________________________________

23. The reclaimed land is helping produce 2 to 3 times more ___________ _________________________per acre.

24. Mr. Casey can now put _____head of cattle where once the land could only support _______. More grazing is available in the _________so his feeding bill is __________.

25. Mr. Utley believes the reclaimed land is __________% better than when they first started mining.

MINING AND RECLAMATION

26. Putting land back the exactly the way it was isn't always the _________way. Scientific research has suggested better ways.

27. Ponds are built to monitor the quality of ________.

28. The ponds eventually are to provide watering sites for __________ and ____________.

29. Two other important reclamation activities are establishing ____________ corridors and _____________trees.

30. In the last ten years over _________acres have been mined and reclaimed.

31. Over __________________tons of lignite have been mined.

32. This is equal to ________________barrels of oil.

33. Lignite has remained a more __________fuel for generating electricity.

34. In Martin Lake as in other mining operations in Texas, a hugh dragline removes the top layer of earth called the __________________.

35. The hugh dragline bucket scoops up to __________cubic feet at a time.

36. The cross pit spreader saves the company ___________of dollars per year.

37. Small haul trucks carry over ______________tons of coal.

38. Coal is then transported to the plant by _________or __________.

39. The overburden is replaced and then the land is _______________. replanted with grass and reforested.

40. The land is revegetated within ______year; for the next _______ years the company maintains and monitors the land. Only then is the mining cycle complete.

CHANGING COAL TO EFFICIENT ELECTRICITY

41. To burn lignite, first it must be ________and _________into the furnaces.

42. The furnace heats a boiler creating __________.

43. The steam turns Hugh turbine generators, producing ___________.

44. The steam is then cooled and condensed with _________circulated from a reservoir/lake built by the company.

45. Electricity is sent to giant ______________out into ______________ lines and then out to customers and businesses over one third of Texas.

46. Burning coal is not a clean process. Burning coal gives off _________and _________.

47. To protect the air, ______________ ______________filter out the fly ash.

48. On newer units, ______________remove sulfur dioxide from the combustion gases.

## FINDING NEW AND BETTER USES OF COAL RESIDUE

49. Industry is finding new and better ways to use a part of the coal that normally would contaminate the air. It is called ______ ________ and is sold as ____________ ___________and ________ ________ materials.

50. At Martin Lake, scrubber residue is processed into ____________and used to manufacture wall board for the construction industry.

51. The generating process is not complete until the _______, _______ and ________are safe and productive.

## A POSITIVE IMPACT ON COMMUNITY

52. The most important cycle remaining is the impact of Lignite on the __________of Texas.

53. The most obvious benefit is cheaper __________.

54. In the first fifteen years the Lignite operation has saved customers over _____________________dollars.

55. Lignite facilities also benefit ___________economies and help generate important tourist dollars.

56. When mining first started out in Rusk County, East Texas there was some initial _______________.

57. The mining facility provided _________jobs, ________became involved in the community and paid over ______ ___________ ___________in taxes.

58. For two counties and three school districts, the mining facility paid over _______ ____________ ____________which was a great impact on the economy.

59. The superintendent of Tatum Schools indicated that student populations doubled when the mining facility was built and employees arrived. The tax base increased _______ ___________. All new school buildings (state of the art design) have been built and ________ _________ and __________ __________ have rapidly increased because of the backing of TU.

60. The ___________, ______________and ______________.These cycles of man and nature work side by side while TU Electric provides the energy needed for all.

# KEY FOR CYCLE OF LIGNITE

## THE HISTORY OF COAL MINING IN TEXAS

1. cattle, forests
2. resource
3. oil, natural gas and coal
4. lignite, low heat
5. 1926
6. natural gas
7. 1953
8. personnel, develop new modern technology.
9. 1970's
10. 1971
11. land, water and air

## PLANNING THE ENVIRONMENT

12. environmental business
13. 1970
14. Biologist with extensive experience in conservation.
15. develop a new set of technologies
16. no
17. before they became problems
18. a committee of environmental experts from various Texas universities were hired to supervise the program
19. graduate research students on fellowships granted by TU
20. naturally return
21. coastal bermuda and crimsom clover
22. worried about restoring the land to its original value
23. pounds of beef per acre than previously
24. 3, 1, winter, less
25. 100

## MINING AND RECLAMATION

26. best
27. water
28. domestic stock and wildlife
29. wildlife and reforested
30. 20,000
31. 300,000,000
32. 700,000,000,000 of oil
33. economic
34. overburden
35. 100
36. millions
37. 130
38. truck or train
39. recontoured
40. one, five

## CHANGING COAL TO EFFICIENT ENERGY

41. crushed and blown
42. steam
43. electricity
44. water
45. transformers, transmission lines
46. sulfur, ash
47. elec. precipitators
48. scrubbers

## FINDING NEW AND BETTER USES OF COAL RESIDUE

49. fly ash, concrete additive, road bed materials
50. gypsum
51. air, water and land

## A POSITIVE IMPACT ON THE COMMUNITY

52. people
53. electricity
54. 4,000,000,000
55. local
56. opposition
57. 1900, employees, 2 million dollars
58. 9 million dollars
59. 10-fold, test scores and achievement scores
60. community, power and environment

# MINING IN A SUITCASE
# STUDENT ACTIVITY

| | |
|---|---|
| Scope & Sequence: | IV Classify resources as renewable and non-renewable<br>III Evaluate positive and negative effects of man on different environments |
| TEK: | 13 Research historical data and determine past practices that have impacted current resource depletion. |
| Materials: | Suitcases containing all of the elements demonstrating the process of coal mining and reclamation.<br>3 Part guide to assist students in observation and recognition<br>Notebook paper for Recorder<br>Dictionaries |

Teacher Preparation: Prepare historical readings to discuss with students the negative impact coal mining has had on people and the environment in the past. Highlight negatives.

Create groups and give each student in the group a task. Give each Recorder a sheet of notebook paper and ask them to draw a line down the middle. On the top have them write Negative on one side, Positive on the other. Tell the groups that the class will be having a discussion about what coal mining was like in America prior to development and application of modern safety and reclamation techniques. Their job is to recognize and write down during the discussion, any positive or negative aspects of coal mining.

Ask the students, what do you know about coal mining? Discuss and measure their knowledge level - correct any misconceptions they may have and begin to discuss and feed them the historical information. Remind them to take their notes and encourage the groups to listen and help the Recorder.

When you feel the groups have enough information, remind the students of the Cycle of Lignite film they viewed. Now, based on memory and the discussion of the film and their note sheets taken during the film have the groups write down any Negative or Positive aspects of how they mine coal today. By this time, they should have a pretty good idea of how things have improved.

Make sure each group has a suitcase and a lab sheet. Ask what the suitcase represents. Tell the students it is called a Surface Mine Model and there are three parts to it, the Pre-Mine Area, the Mining Area and the Post-Mine Area. In each area are numbered flags. The students are to label the activity in each area by number.

As groups finish, ask them to answer the following questions: Although group discussion is fine to come up with answers. each student must have his own answer sheet for the Post Lab.

I. Give the names of at least three types of equipment used in coal mining.

2. Analyze the data from the positive and negative sheet and give a group opinion as to whether you believe its okay to mine coal as long as the land is replaced in better condition than it was before the mining took place. Give three reasons why you believe your opinion is correct.

3. Tell why your group would or would not be workers in the coal mines of long ago.

4. Define surface, geology and overburden. Use your dictionaries.

5. Name three different kinds of careers available during Pre/Mining/Mining/Post Mining that are connected to taking care of the environment.

# MINING IN A SUITCASE
# STUDENT ACTIVITY LAB SHEET

## PRE-MINING

ACTIVITY FLAG NUMBER

A. DRILLING FOR GEOLOGY INFORMATION ____________

B. CLEARING AND WALKWAY PREPARATION ____________

## ACTIVE MINE AREA

ACTIVITY FLAG NUMBER

A. DRAGLINE REMOVING OVERBURDEN ____________

B. LOADING LIGNITE INTO HAULER ____________

C. HAULROAD ____________

## POST MINING AREA

ACTIVITY FLAG NUMBER

A. SOIL LEVELING ____________

B. PLANTING ____________

C. RECLAIMED AREA ____________

## COAL - STUDENT ACTIVITY 3
## LIGNITE & BOTTOM ASH & FLY ASH, OH MY!!!!!!

Scope & Sequence:
Evaluate positive and negative effects of man on different environments
Classify non-renewable resources
Identify common elements

Practice Math/Science TAAS skills
Measuring/Weighing/Scientific Process

Materials:
Samples of lignite coal, bottom ash and fly ash
Cement mixed Sakrete
Water
Paper cups and large spoons/scoops
Paper towel holders or molds 1x1x12
Large cement blocks with openings
Weights (bricks/regular weights at least 5 lbs)
Safety data on fly ash

Safety:
Follow safety rules cement/fly ash - wear masks along with eyewear, aprons - spray fly ash with misting water bottle - discuss safety

Teacher Preparation: This is an extended lab - set up a place in class to store samples until they dry and are ready to test. Test outside. Make sure you have plenty of newspapers spread on tables or floor before beginning lab.

Divide students into groups of four - designate responsibilities (a safety monitor is suggested). Give each group portions of cement mix, ash, water and molds/tubes. Have several balances at stations for student use.

Pre-Lab: Using the samples of coal and ash, ask students what it is. Ask, Do you know what happens to coal after it is burned to create electricity? Explain the element forms (gas) that become part of air as well as the solids left behind after coal burning. Explain that coal residue (fly and bottom ash) is recycled. Ask students, Does anyone know what fly ash is used for? Explain that power companies supply fly ash to cement manufacturers extending/strengthening the product. Tell them they will be testing this idea to see if it is true; they will also have an opportunity to develop a sample of their own.

Work with students to help them develop a group hypothesis based on which cement sample would support the most weight. Help them design a procedure for testing based upon the following information:

1. A control sample would have 50% water- 50% Sakrete only
2. A 2nd sample would use proportions 3 3/4% cement to 1 1/4 ash and 50% water
3. A 3rd sample would be whatever proportions the group decided.

Lab:

After deciding and recording their hypothesis and procedure, they must next measure and weigh their mix for each sample and record it. Have students label their sample molds, mix and pour. It will be messy but that's okay. Set samples to cure for at least seven days before testing.

The next day, repeat the process and set samples to cure for 28 days. On the third day have students create data tables on which to write their results.

On testing day, have students build stations of concrete blocks. Attach heavy duty cord or rope around samples one at a time and tie five pound bricks or weights, one at a time and record at what weight each sample breaks. 1x1x12 rectangles should hold up to 30 lbs of weight prior to breaking. Record at seven days, then 28 days and compare results. Students should have better results at 28 days because fly ash weakens concrete at 7 days, strengthens it at 28 days. or the longer it cures.

Water strengthens concrete so to add another variable, have students soak one or more samples in concrete to see if this affects their results.

Post-Lab: Students write up results/conclusions at both 7 and 28 days. This reinforces the idea that research is continuous, ongoing and not a one day event in real life. Have them do a comparison, critique with improvement suggestions when completing the final writeup. This could be homework.

Extension: Put samples of bottom ash and fly ash in paper cups filled with distilled water. Take pH readings before and after it sits for seven days to test acidity. Fly ash may harden in cup but that's okay - it shouldn't affect results.

This experiment was patterned after the Flexural Beam Test often used in industry. Thank you to Jacob Gonzales, TU Engineer, Fossil Production

Uses for bottom ash - gravel to pave roads, layered traction in muddy areas and replaces use for sand in asphalt roads.

# STUDENT LAB SHEET
# LIGNITE, ASH OH MY!!!

Problem: Given cement, water and fly ash, can we make a product that can hold 30lbs of weight?

Hypothesis:________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

Procedure:_________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

Create your data table here

Results/Conclusion______________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________

I did/did not like this lab______________________________
because_________________________________________________

If we could have
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________

it would have been a better experiment
because_________________________________________________
________________________________________________________

Score: Teamwork________________Quality of work__________

I have
learned_________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________

## STUDENT ACTIVITY 4 - A CLEAN SWEEP!!!!!

### MINI LESSON - Match types of Industrial Cleaners to Operating Function

Scope & Sequence: Evaluate positive/negative effects of man on different environments
Classify non-renewable resources

Materials: Envelope with pictures of four cleaners and
Separate discriptions of each cleaner - per group
Glue sticks/sissors/map colors/markers/rulers
Pens/pencils/3-4 sheets of colored unlined paper

Teacher Preparation: Prepare one envelope per group containing cut up pictures of four cleaners and cut up descriptions of each along with sets of materials as listed above.

Pre-Lab: Show picture of cyclone cleaner - ask students what they think it is and what it does. Explain that it is a type of "air" cleaner used to eliminate pollutants in the air. Tell the students that there are several different kinds of machines used to clean air and that they work on different principles. It is their job to discover the names of these machines and how they operate.

Lab: Have Materials Managers pick up their envelopes. The task is to create a texbook out of the materials given that explains the different kinds of cleaners. The book must include a title, authors names, matched cleaners and descriptions and must be more than one page. Bonus points are given for including a Table of Contents and Glossary. Use Graphic Organizers.

Students should be able to match correctly and include the following: The principle upon which each machine operates - static electricity, centrifugal force, filters and washing. Post lab is an oral critique of finished products.

Extensions or Homework: Review Safety Data Sheet Number 135B provided on fly ash. Explain this is provided on all residues/pollutants that contaminate air/water in industry.

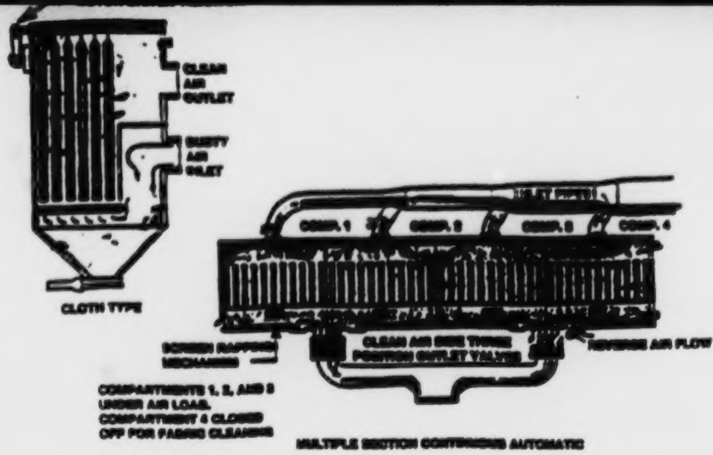
Students investigate and list facts in data table form on elements contained in fly ash. Variables include percentages, water solubility, appearance, odor, first aid procedures and handling.

Students graph element percentages. Decide what goes on x and y axis - title, form of graph, is there a key or legend? What will it look like?

Students research Pneumoconiosis.

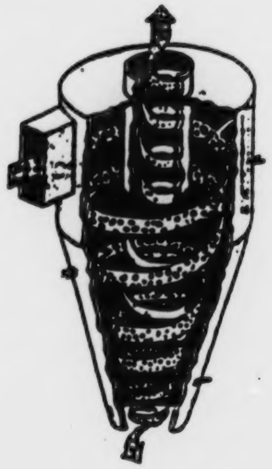
Students develop safety posters illustrating the proper way to handle fly ash in the classroom. No dust - mix fine spray water mist to cut down on dust. Or develop posters illustrating how fly ash is used as a byproduct.

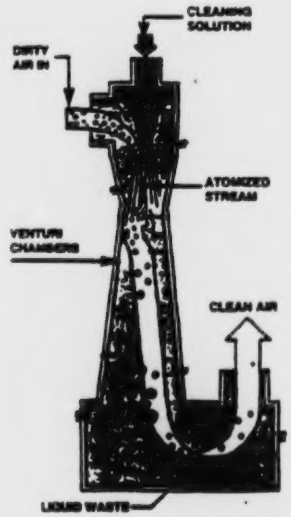
The above activity was developed as a result of support and materials provided by Mr. Ed Cooley, TU Engineer.


CLEAN
AIR
OUTLET
DIRTY
AIR
INLET
CLOTH TYPE
INLET PIPES
COMP. 1
COMP. 2
COMP. 3
COMP. 4
SCREEN RAPPING
MECHANISM
CLEAN AIR SIDE THREE
POSITION OUTLET VALVES
REVERSE AIR FLOW
COMPARTMENTS 1, 2, AND 3
UNDER AIR LOAD.
COMPARTMENT 4 CLOSED
OFF FOR FABRIC CLEANING
MULTIPLE SECTION CONTINUOUS AUTOMATIC

Baghouses - filter made of cloth/paper/similar material - can collect 98% of particulates - used in steel mills, foundries

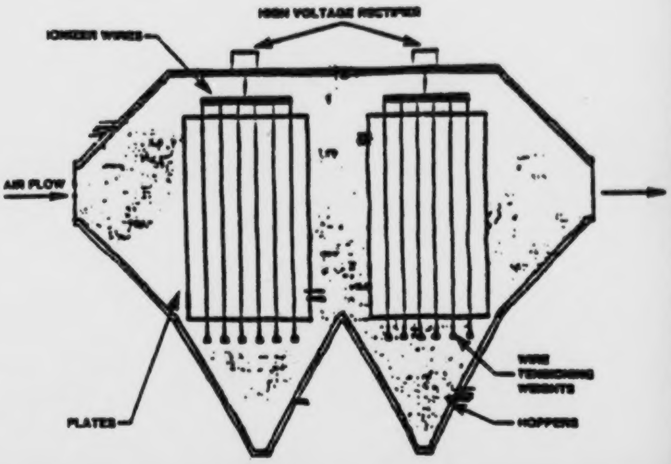
Cyclones - Centrifugal force particles are thrown against the walls of a cylinder - can collect 95% of solid pollutants - used by cotton gins, rock crushers




CLEANING
SOLUTION
DIRTY
AIR IN
ATOMIZED
STREAM
VENTURI
CHAMBERS
CLEAN AIR
LIQUID WASTE

Wet scrubbers - clean gases/air by "washing" - used by coal burning power plants, asphalt/concrete plants and other facilities that emit sulfur dioxides, hydrogen sulfides and other gases.

Electrostatic Precipitators - static electricity - particles attracted to negatively charged plates - 98 to 99% effective - used instead of baghouses by power plants, steel and paper mills.


HIGH VOLTAGE RECTIFIER
IONIZER WIRES
AIR FLOW
WIRE
TENSIONING
WEIGHTS
PLATES
HOPPERS

# ACID RAIN
## STUDENT ACTIVITY 2 - LAKES ALIVE!!!!

Scope & Sequence:
Explain causes/effect of acid rain
Evaluate positive/negative effects of man on different environments
Technological advances and careers in science

Materials:
Balloons - Coat Hangers - Plastic Grocery Bags
Pepper/punch holes/rice krispies
Tube holders for fluorescent bulbs - Hair dryer

Day I: Students will be creating their own electrostatic precipitator while investigating static electricity and "Bernoulli's Principle".

Pre-Lab: Have students examine pictures of various technological cleaners used by industry to clean air. Discuss how industry is just one producer of air pollution. Ask what kinds of pollution are produced by industry. Explain that industry developed cleaners to limit/eliminate acid rain. Emphasize the electrostatic precipitator and wet scrubber.

Question students to see if they remember that the electrostatic precipitator works on the principle of static electrical charges attracting particles where they are removed.

Give each two/three students a balloon along with a small amount of black pepper. Have students inflate and tie their balloon. Tell them to rub the balloon on hair or classmate's back then hold the balloon over the pepper. What happens to the pepper? Why? Have them record their observations. Find out levels of knowledge by asking who knows what concept they have just explored? (Static electricity)

Lab: Tell students you want them to experiment to see if they can create a mock electrostatic precipitator in the lab. They are to use a coat hanger, a grocery plastic bag and a fluorescent tube holder on their tables. Review their pre-lab and ask what was present when they made static electricity with the balloon (movement, friction) and then give them some hints:

1. The bag must be attached to the coat hanger
2. There must be some movement
3. Electrostatic precipitators attract particles and bits of dust and lint just like static electricity.

Students will try all sorts of odd things but eventually someone will come up with the answer. The rest will copy and learn. (Attach the plastic bag to the coat hanger and then move them through the tube. The bag, moving through the tube, strips the negatively charged electrons from inside the tube making the overall net charge positive. Anything that has a negative charge will be attracted to the tube because opposites attract. Have samples of punch holes, pepper or rice krispies ready for them to test.

Guide students through the final step of the activity by holding an electric hair dryer so air stream blows across the top of the tube. The air mass creates a low pressure area at the top and the greater air pressure at the bottom pushes the punch holes up the tube.

Results should be as follows: If the tube is charged the punch holes will stick to the sides (static electricity);

If the tube is not charged, the holes will shoot out in a spray (Bernoulli's Principle). This is what would happen if the precipitator shut down.

Make certain students record the procedure they developed as well as their results. Elaborate by allowing students to test the pepper and the rice krispies for possible variation in behavior.

Post-Lab: Students write conclusion that includes opinion stating which sample was most representative of air particulates - pepper, punch holes or rice krispies and why. This can be assigned as homework.

Day Two

Teacher Preparation: Have "wet" scrubber set up for class ahead of time. You have a choice - use a demo or have groups build their own. Either way, you are using glass so more classroom structure is needed. Go over safety on glass prior to beginning.

Materials:
paper towels
12cm piece of glass tubing - 3 55ml flasks
three 2.5 cm pieces of glass tubing
two glass impingers (glass tubing drawn at one end to give it a smaller diameter so as to let out smaller bubbles)
heat source (bunsen burner/hot plate
three 2 hole rubber stoppers (of a size to fit the mouths of the flasks
two 30 cm pieces of rubber tubing - vacuum source(pump)

Refer students back to data on "wet" scrubbers. Tell them it is one of the most common pollution control devices used by industry. It operates on a very simple principle: a polluted gas(air) stream is brought into contact with a liquid(water) so that the pollutants can be absorbed. It is washing with water.

# ACID RAIN - LAKES ALIVE
# STUDENT ACTIVITY SHEET

Post-Lab
Answer the following questions:

I. Why does the water in the wet scrubber change color?

2. Why does the wet scrubber have an impinger (in other words, why is it important for small bubbles to be formed)?

3. What does the scubber filter out of the air? not filter out?

4. Suggest ways to dispose of the pollutants that are now trapped in the water.

After learning about industrial cleaners and simulating two of them in the lab, write an opinion as to whether or not you believe industrial cleaners are effective.

Procedure:

1. Check your apparatus to make sure all the connections are made. Next, put a paper towel into a 55 ml flask and place above burner.

2. Make an airtight seal with the flask using a 2 hole stopper. Insert the 12 cm section of glass tubing through one of the holes. Tubing should reach to approximately 1.2 centimeters from the bottom of the flask.

3. Insert a 2.5 cm piece of glass tubing into the other hole of the stopper.

4. Connect a 30 cm piece of rubber tubing to the 2.5 cm piece of glass tubing making sure an air tight seal exists.

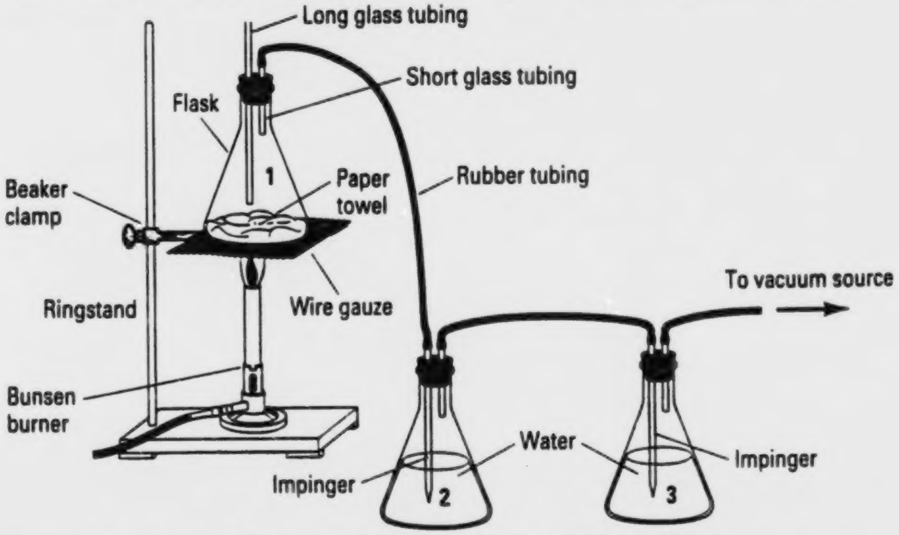
5. Fill a second 500 ml flask approximately 3/4 full of water. Using a second double hole stopper, put a 2.5 cm piece of glass tubing into one of the holes and insert the glass impinger into the other.

6. Construct a third flask like the second.

7. Connect the rubber tubing and heat the first flask COMBUSTION CHAMBER until smoke appears.

8. Put a vacuum pump on the third flask to draw a stream of smoke through the second flask WET SCRUBBER. If smoke collects in the second flask above the water, a second scrubber should be added.

9. After observation, answer the questions on your lab sheet.


Long glass tubing
Short glass tubing
Flask
1
Paper towel
Rubber tubing
Beaker clamp
To vacuum source
Ringstand
Wire gauze
Bunsen burner
Water
Impinger
2
3
Impinger

Adapted information from Office of Air Quality, State of Texas
WET SCRUBBER - Addison-Wesley Publishing Co., Inc. All Rights Reserved

# WILDLIFE

## COUNTING THE BIRDS

Scope & Sequence: Careers in Science
Positive/Negative effects of man on environment
Classify Resources a Renewable/Non Renewable

TEK: Collecting data
Related graphing and math skills

Materials: Survey form and clip board
Supportive materials on bird behavior
Supportive materials on bald eagle behavior
Lake Fairfield Eagle Brochures

Pre-Lab:

Divide students into groups. Pass out Eagle brochures and let them examine them. Ask, does anyone have a question about Bald Eagles? Ask, does anyone have information they can share about Bald Eagles? Correct any misconceptions - talk abut endangered status and read over material that shows how a count has been taken at Lake Fairfield every year to make sure they were not being disturbed.

Ask students to examine the data and see what stands out. Ask if they have any idea why there were almost twice as many Eagles at Lake Fairfield in 1989. Then, have them make up a hypothesis as to numbers of birds they might see.

Lab: Explain that they are going out to count urban birds around the school area (or park, zoo) They will be given specific routes to take and timed for a class period. Everything must be recorded. Go over the activity sheet. Tell them a time to meet with results.

Post Lab: Students in their groups create/record their data - then come to a consensus as to why or why not the birds were there to count. Students write results/conclusion giving opinion and how to strengthen lab activity.

Extension/Homework: Using the Texas Bald Eagle Survey, assign different graphing assignments based on information given.

Have students choose what they want to graph and how - assign a minimum of ten items to graph. Discuss graphs in class the following day looking at the various data and considering possible variables.

# URBAN BIRD SURVEY
# STUDENT LAB SHEET

PLEASE COMPLETE ALL SECTIONS OF THIS FORM.

GROUP OBSERVER NAME________________________

Name of Recorder____________________________

No. of Observers_______ Survey Date_________________

State______________City___________Site #___________

Start Point:_________________Stop Point:________________

Were you unable to complete the route for some reason?______
_______________________________________________________

Procedures: Start Time__________Total time of Survey______

Survey method: Circle One Foot travel Road Vehicle Other

Roost__________Non Roost_________

Total birds counted___________No. of adults_______

No. of immatures__________

Address_______________________Phone #_______________

### Summary of bald eagle observations during the 1995 mid-winter survey in Texas

| Standardized Survey Locations | Bald Eagles Observed Adult | Immature | Unkown | Total | Golden Eagle Observed Adult | Immature | Unkown | Total | Number Counties | Survey Time(min.) | Number of Observers |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Livingston(TX-1) | 5 | 1 | 1 | 7 | 0 | 0 | 0 | 0 | 3 | 600 | 9 |
| Sam Rayburn Reservoir(TX-2) | 5 | 8 | 0 | 13 | 0 | 0 | 0 | 0 | 4 | 600 | 54 |
| Lake O' the Pines (TX-3) | 23 | 10 | 0 | 33 | 0 | 0 | 0 | 0 | 1 | 180 | 19 |
| Wright Patman Reservoir (TX-4) | 11 | 2 | 0 | 13 | 0 | 0 | 0 | 0 | 2 | 390 | 3 |
| Buffalo Lake NWR (TX-5) | 4 | 2 | 0 | 6 | 3 | 0 | 0 | 3 | 1 | 175 | 2 |
| Lake Meredith (TX-6) | 16 | 4 | 0 | 20 | 1 | 0 | 0 | 1 | 3 | 360 | 6 |
| Lake Conroe (TX-7) | 3 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 190 | 6 |
| Lake Warren (TX-8) | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 165 | 2 |
| Lake Buchanan (TX-9) | 3 | 6 | 0 | 9 | 0 | 0 | 0 | 0 | 3 | 120 | 12 |
| Lake Texoma (TX-10) | 23 | 7 | 0 | 30 | 0 | 0 | 0 | 0 | 1 | 180 | 11 |
| Lake Fairfield (TX-11) | 4 | 14 | 0 | 18 | 0 | 0 | 0 | 0 | 1 | 120 | 11 |
| Laguna Atascosa NWR (TX-12) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 60 | 1 |
| Attwater Prairie Chicken NWR (TX-13) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 60 | 1 |
| Lake Tawakoni (TX-14) | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 60 | 2 |
| Lake Fork (TX-15) | 24 | 23 | 5 | 52 | 0 | 0 | 0 | 0 | 2 | 180 | 50 |
| Toledo Bend Reservoir (TX-16) | 4 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 164 | 14 |
| Lake Whitney (TX-17) | 5 | 10 | 0 | 15 | 1 | 0 | 0 | 1 | 2 | 480 | 10 |
| Garwood/Eagle Lake Rice Prairies (TX-18 | 3 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 90 | 1 |
| Lake Palestine (TX-19) | 39 | 12 | 0 | 51 | 0 | 0 | 0 | 0 | 4 | 540 | 9 |
| Lake Cooper (TX-20) | 1 | 5 | 0 | 6 | 0 | 0 | 0 | 0 | 2 | 60 | 4 |
| Lake Pat Mayse (TX-21) | 8 | 6 | 0 | 14 | 0 | 0 | 0 | 0 | 1 | 90 | 3 |
| Palo Duro Lake (TX-22) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GRAND TOTAL** | **184** | **113** | **6** | **303** | **5** | **0** | **0** | **5** | **42** | **4864** | **230** |

* Texas side of lake counted only.

## Review List of Materials

### From the Internet

Louisiana State University - Michael Brown, Faces of Science, African Americans in the Sciences, Copyright 1995, www.lib.lsu.edu/lib/chem/display/easley.html

Electricity - #1 - 18 - Bill Nye, The Science Guy, Episode 2-04, Electricity, Why is it so warm in here?, July 8, 1996, //nyelabs.kcts.org/nyeverse/shows/el18.html

Electricity - #2 - 04 - Bill Nye, The Science guy, Episode 2-04, HEAT, I think I just burned myself!! Heat conduction, //nyelabs.kcts.org/nyeverse/shows/e204.html

Electricity -Energy and Science Projects for Students - Lemon Power, www.energy.ca.gov/energy...ojects/projects-html/lemon.html

Air Pollution - TNRCC, Office of Air Quality, Air Pollution Lesson Plans and Data, Measuring Physical and Chemical Properties of Matter, Comparing Precipitators and Wet Scrubbers in the Classroom, June 6, 1996 - www.tnrcc.state.tx.us/ai...lessons/airpollutionlesson.html

Air Pollution - TNRCC, Particulate Information and Data, Monitoring Particulate Matter in Major Texas Cities, Comparing Suspended Particulates and a Solution; Classifying Common Atmospheric Gases/Particulates in the Classroom, June 6, 1996 - www.tnrcc.state.tx.us/air/monops/lessons/partinfo.html

Wetlands - USDA, Better Wetlands, How to Build a Song bird or Bat House, July 3, 1996, www.ia.nrcs.usda.gov/enhance/bwpg12.html.

Alternative Energy - LEERIC, Parabolic Solar Collectors, July 8, 1996, www.leeric.lsu.edu/educa/lesson3.htm

Alternative Energy - Energy and Science Projects for Students, Experimenting with Water to Product Energy, Moving Water, Moving Blades, July 8, 1996, www.energy.ca.gov/energy.../projects-htm/waterenergy.html

Alternative Energy - Energy and Science Projects for Students, Measuring the Wind, July 8, 1996, www.energy.ca.gov/energy.../projects-html/windmeasure.html

Alternative Energy - Energy and Science Projects for Students, Solar Hot Dog Cooker, July 8, 1996, www.energy.ca.gov/energy...ts/projects-html/solardogs.html

Alternative Energy - Solar Box Cookers Northwest, The "Minimum" Solar Box Cooker, A great solar oven you can build quickly from two cardboard boxes, July 8, 1996, www.accessone.com/`sbcn/minimum.htm.

Mathematics - Toronto Blue Jays Baseball Club, Toronto, Canada, Baseball Math, July 8, 1996, www.bluejays.ca/bluejays/jjzone/bbmath.htm

Mathematics - Math Forum, Calculating Tips and Tricks, Squaring Numbers, January 14, 1996, //forum.swarthmore.edu/k12/mathtips/2digit5.html or 1-800-756-7823.

Mathematics - AIMS Education Foundation, Problem Solving Puzzles by the Month, Square Stumper, Squarely Constructed 1 and 2, Lost in Space, Are All Sides Equal, The Heart Breaking Puzzle and Time Marches On, January through July, 1996, July l, 1996, //204.l6l.33.100/Puzzle/square/squarel.html

Endangered Species - Wolves, Science Museum of Minnesota ,30 East 10th Street, St. Paul, Minnesota 55101 or 1-800-221-9444, ext. 4747 Lesson Plans on behavior, characteristics, etc. on wolves and dogs. July 12, 1996, gopher://gopher.informn...12/wolfguide/4/42

Other Sources

Endangered Species - Bald Eagles, Lake Fairfield, Big Brown Mining, TUElectric and Texas Parks & Wildlife, l995 Mid Winter Survey & Fairfield Lake Eagle Tour Brochure, Richard White

COAL, Cycle of Lignite Video, TUElectric, Orlan Ihms
Surface Mining in a Suitcase, TUElectric, Orlan Ihms
Wet Scrubber Photo-Addison Wesley

**Nancy McGreger**

**Biology**

**Stroman High School, Victoria**

**Texas A&M University Biochemical**
**Department, College Station**
**Dr. Bruce McDonald, Mentor**

# TTIP
## CURRICULUM IMPLEMENTATION PLAN
## Abstract

NAME: Nancy McGreger

INTERNSHIP: Texas A&M, Department of Plant Pathology

SCHOOL: Stroman High School, Victoria I.S.D., Victoria, Texas

PRIMARY SUBJECTS: Biology I/II

ACTIVITIES: Growth Study of *Neurospora crassa* using Race Tubes. Demonstration of Basic Genetic Principles using *Neurospora crassa*.

OBJECTIVES: Students will measure and record rates of growth. Students will practice aseptic technique. Students will display information obtained in a graphical form. Students will become familiar with basic microbiology and genetics words.

SUMMARY: Students will perform a lab using the fungus *Neurospora crassa*. From this lab,students will gain knowledge in the areas of microbiology, genetics and mycology. Important laboratory techniques such as measurement, data recording and aseptic technique will be emphasized.

RESOURCES:

*Dr. Bruce McDonald, Department of Plant Pathology
*Dr. Dan Ebbole, Department of Plant Pathology
Texas A&M University
College Station, TX 77843

*Ryan, Beadle and Tatum, "The Tube Method of Measuring the Growth Rate of *Neurospora*", American Journal of Botany, Volume 30, pp. 784-799, Dec. 1943.

*The Internet, World-wide-web

* The Fungal Genetics Stock Center
University of Kansas Medical Center
Kansas City, KS 66160-7420
Ph: 913-588-7044

# General Information on Fungi

When the word fungi is mentioned, most people probably think of mushrooms. Actually a mushroom is only one type of organism in an entire kingdom of very diverse organisms. There are many amazing and important things about fungi.

## Interesting Facts about Fungi:

*The world's oldest and largest organism is a fungus. It was discovered in a forest in Michigan. After taking many samples and measurements, scientists estimated that this fungus is at least 1500 years old, covers 15 hectares and weighs over 22,000 pounds, which is more than a blue whale, the largest living mammal.

*King Tut's revenge is actually *Aspergillis flavus*, a fungus. When King Tut's tomb was opened, many people apparently died due to the mummy's curse.. Scientists now think that *Aspergillis flavus* were growing on the mummies and food stored with them. When the door was opened, large amounts of spores were blown into the air and people breathed these spores. These spores produce toxins which when present in large amounts are capable of killing people.

## Positive Effects of Fungi:

*Fungi are food producers as well as sources of food. Some fermented products of fungal metabolism are soy sauce, bread, beer, wine. Fungi also serve as foods like truffles, morels and other types of edible mushrooms.
*There are medical applications of fungal products such as the chemical Cyclosporin, without which organ transplantation would not be possible. Cyclosporin suppresses the immune system which prevents tissue rejection allowing the transplanted organ to remain unrecognized as foreign by the body's immune system.
*Antibiotics are mainly products of fungi. They are used in killing bacterial infections in the body.
*Fungi play an important role in ecology. Fungi are important in maintaining the ecological balance of the environment by breaking down dead organisms, recycling nutrients, etc.

## Negative Effects of Fungi:

*Fungi are responsible for causing large amounts of economic damage by reducing crop yields by 20-30% worldwide.
*In addition to crop damage in the field, fungi also decompose finished products and stored crops.
*Fungi create toxins called aflatoxins which cause cancer. These toxins lead to death in many other parts of the world.
*Fungi cause disease in AIDS victims through opportunistic infection, colonizing lung tissue and other body parts, eventually resulting in death.

## Descriptions of Experiments using *Neurospora crassa*

As you can see, fungi have a large effect on our daily lives. As a teacher, I find that not many of my students are familiar with fungi. I have also noticed that there is very little information in high school textbooks on this subject. Keeping this in mind, I have tried to develop some simple experiments using fungi which teach basic principle of biology and genetics.

The filamentous fungus *Neurospora crassa* was chosen for classroom experiments for many of the same reasons researchers use it. It is inexpensive, small, easy to maintain, grows rapidly and is safe to work with and easy to dispose. An added plus is that this is the organism that was researched by Nobel prize-winning scientists Beadle and Tatum in their pioneering work in genetics and biochemistry in the 1940's. Since *Neurospora* is a model organism and has been extensively studied, a large amount of information is known about this organism. There are many different mutants available that lend themselves well to the study of biochemical pathways, circadian rhythms, complementation, recombination, phenotype, genotypes etc. These mutants have been used to design experiments which illustrate simple genetic principles.

## EXPERIMENTS

RACE TUBES : One simple experiment which we performed was to measure *Neurospora* growth rates in an apparatus called a "race tube". A race tube is essentially a tube or pipette in which a thin layer of growth medium is poured and placed horizontally to solidify. These race tubes can then be inoculated with different *Neurospora* mutants and the hyphae will grow toward the opposite end of tube. We used the wild type and a ropy mutant. The hyphae of ropy

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mutants grow in a curved and branching fashion which reduces the distance it can grow as compared to the wild type, which has straighter filaments and less branching. Using the laboratory protocol given, students can work in groups of two. The teacher can give each student a different strain and the students can conduct "races" with their fungi to see which strain can grow faster.

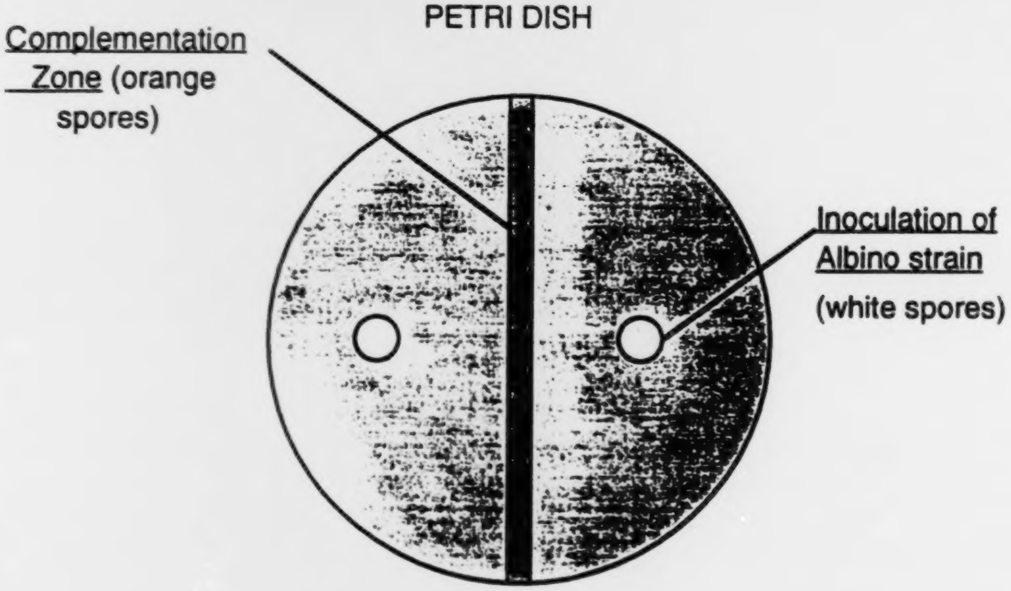
CIRCADIAN RHYTHMS: Fungal growth and sporulation are determined by circadian rhythms. Race tubes can be inoculated, left in the light for a few hours and then covered with aluminum foil. They are left in the dark 2-3 days and then uncovered and bands of sporulation are marked. The distance between the bands and the time are figured which results in the length in hours of that particular strain's circadian rhythm. This can be compared with the frq mutant and the ropy mutant which have different rhythms.

TYPES OF GROWTH:: Two types of fungal growth can be examined, yeast growth and filamentous growth. Yeasts grow by budding and *Neurospora* grows by extending filaments called hyphae. Petri dishes can be inoculated with bread yeast and *Neurospora*. Allow these cultures to grow at room temperature several days and have students observe the dishes every day. The observations recorded should be part of the lab report. If the equipment is available, it is also interesting to observe these petri dishes under a dissecting microscope as well as observing wet mounts under a compound microscope. The differences between the types and rates of growth are clearly evident. This simple experiment shows that yeasts grow better in a liquid type of environment than on the surface of agar, whereas the filamentous *Neurospora* grows very rapidly and covers the dish in a short amount of time. This would be important in understanding how certain types of fungi are able to colonize a substrate quickly whereas others cannot. For example, it makes sense that yeast would grow better in liquid environments like beer and wine and that filamentous fungi would do better on solid substrates where it could extend its hyphae long distances.

GENETIC ANALYSIS: *Neurospora* can also be used to perform a simple genetic analysis which illustrates basic genetic principles as well. Using mutants with different colors of spores, it is easy to design experiments that show the relationship between genetics and biochemistry. Knowing that genes control the biochemistry of an organism, it is possible to demonstrate the genetics of certain biochemical pathways using phenotypes to show what genotypes were present.

Complementation: It is possible to do complementation experiments where two mutants that are lacking genes to complete two different steps in a biochemical pathway are grown in close proximity. This allows the products of their respective functional genes to be shared externally, which would theoretically enable both mutants to complete the pathway. This would be shown by a color change in the area that complementation is occurring. For example, two albino mutants make white spores but would have an orange color where the two different mutant hyphae meet and orange spores are produced. To do complementation, you must have the same mating type and different loci. For example, use strains 4659 (mutation in the al-2 locus) and 4661 (mutation in the al-3 locus). These strains would complement. In another example, strains 4657 and 4663 would not complement because they both have mutations in the al-1 locus.

Complementation Experiment:
On a petri dish containing *Neurospora* growth medium, inoculate one side with strain 4659 and one side with 4661. After about 3 days, the filaments should cover the entire dish. Observe the dish for several days after the filaments meet. The zone of complementation should run down the middle of the plate and be evident as an orange line where orange spores form.


PETRI DISH
Complementation Zone (orange spores)
Inoculation of Albino strain
(white spores)

# FUNGAL GROWTH STUDY

Growing *Neurospora crassa* in Race Tubes

## OBJECTIVES:

1. Students will measure the rate of growth of the filamentous fungus *Neurospora crassa*.
2. Students will learn aseptic technique as it applies to the preparation of microbiological media and transfer of fungi.
3. Students will record growth rate data and report their results graphically.
4. Students will compare phenoptypes of various mutants.

## MATERIALS NEEDED:

1. 25 ml presterilized, plugged plastic pipettes.
2. Pipe cutter
3. Pipette bulb or pump
4. Sterile caps for the ends of pipettes (Kim-Kap disposable caps-from Fisher Scientific)
5. 95% ethanol
6. Disposable latex gloves
7. Double-sided tape or clothespins
8. *Neurospora crassa* mutants-at least two different mutants, (ropy, albino, wild-type)
9. Metric rulers
10. Hot plate (preferably with stirring capability) or Bunsen burner
11. Glass stirring rod (if hot plate does not stir)

## IMPORTANT TIPS:

*This lab has been designed for each student to have their own race tube, working in pairs with each growing a different strain. The best situation is to have one ropy strain and one regular strain. Note: The albino and wild-type strains are much faster growing than the ropy strain.

*Disposable caps can be sterilized in ethanol.

*When cutting pipettes, have sterilized caps ready to place over cut ends.

*Fill pipette up to 25 ml mark, then dispense all but 12 ml back into flask. This covers the inside of pipette and minimizes condensation.

*Disposal of Race Tubes and *Neurospora crassa* Cultures: *Neurospora* is a harmless organism which can simply be disposed of in the trashcan.

*It is possible that the correct type of glass pipettes can be reused, but must be cleaned and autoclaved first. It is not recommended that disposable glass or plastic pipettes be reused.

*The teacher might want to inoculate a petri dish about 4 days ahead of time to grow up a large culture for use with multiple classes.

## PROCEDURE:

Preparation of *Neurospora crassa* growth medium: When preparing media, approximately 25 ml is needed per petri dish and 15 ml per race tube.

| For 100 ml: | For 1 Liter: |
|---|---|
| 1. Yeast extract=0.5g | 1. Yeast extract=5 g |
| 2. Proteose Peptone #3 (Difco)=0.5g | 2. Prot. Pep. #3=5 g |
| 3. Bacto-Agar=1.5g | 3. Bacto-Agar=15 g |
| 4. Maltose=4.0g | 4. Maltose=40 g |

1. Measure the dry ingredients into an appropriately sized Erlenmeyer flask. Be sure the volume is no more than half of the volume of the flask. For example, the 100 ml recipe should be made in at least a 200 ml flask.

2. Using a graduated cylinder, add the remaining volume of distilled water and stir well.

3. Place a square of aluminum foil loosely over the mouth of the flask.

4. Heat the flask on the hot plate on high until the medium is about to boil, then lower to a medium temperature. Do not allow the flask contents to boil over.

5. Boil gently for at least 20 minutes to sterilize medium.

6. Remove flask from heat and allow it to cool until you can comfortably touch it with your hands.

## Preparation of Race Tubes:

1. Prepare *Neurospora* growth medium as directed in the recipe above.

2. Place pipette bulb or pump onto plugged end of pipette and slowly draw 25 ml of medium into flask. Let all of the medium but 12 ml drain back into the flask. Make sure you are reading the correct side of the pipette.

3. Dip gloved finger of free hand into small beaker of ethanol.

4. Cover open end of (non-plugged) pipette with sterilized glove finger.

5. Keeping your eyes on the plugged end, slowly place filled pipette (lowering the plugged end first) onto tape or clothespin, taking care not to wet the cotton plug.

6. Do not touch the pipette until the medium is cool and solidified.

7. While medium is cooling, sterilize the plastic cap by dipping it into ethanol and allowing it to air dry (open side down)..

8. When medium in the race tube is cool and solid (it should look opaque), clamp the pipe cutter gently onto the open end of pipette, make one or two full circles and gently snap off the end of the plastic pipette.

9. Cover the open end of the race tube immediately with a sterile plastic cap.

10. Secure the cap with masking tape and place the tube in a secure place.

Inoculation of Race Tubes with *Neurospora*: :

1. Obtain a pure culture of *Neurospora* and inoculate your race tube with an inoculating loop. Be sure to use aseptic technique. See attached instructions if you are unfamiliar with this technique. If a laminar flow hood or a still air chamber is available, perform the inoculation of race tubes there.

2. Place inoculated race tubes in a secure place and mark the exact place of inoculation on the outside of the race tube with a Sharpie or other indelible marker.

3. Measure the amount of growth daily in millimeters, marking each growth front as close to the same time as possible each day.

4. Students should make a graph with recorded data. Be sure to label the axes correctly and include the units used. When graphs are complete, answer the student questions.

NAME_______________
CLASS_______________
DATE_______________

## *NEUROSPORA* LAB QUESTIONS

1. What does aseptic mean? ______________________________

2. What is *Neurospora crassa?* ______________________________

3. Why is it important to keep aluminum foil over the mouth of the flask during and after boiling? ______________________________

4. In the Preparation of Medium, Step #2, the instructions state that you are to release some of the medium back into the flask. Is the released medium contaminated at this point? Why or why not?

5. Name at least three possibilities for contamination of the medium in this experiment: ______________________________

6. Do you think the medium will show bacterial contamination after a few days at room temperature? Why or why not? _______________

7. Predict how much or how far the fungus will grow in 24 hours:

8. After two days of growth, how far do you think the fungal growth front will be?________________________________________

9. What is the difference between the wild-type and mutant strains?

____________________________________________________

10. How is the growth of a filamentous fungus different than other cells such as plant, animal or bacterial cells?____________________

____________________________________________________

____________________________________________________

VOCABULARY LIST Define the following words. Be sure to give a complete definition for each word.

1. Filamentous-________________________________________
2. Aseptic-___________________________________________
3. Agar-_____________________________________________
4. Petri dish-_________________________________________
5. Race tube-_________________________________________
6. Growth medium-_____________________________________
7. Mutant-___________________________________________
8. Wild type-_________________________________________
9. Contamination-_____________________________________
10. Phenotype-_________________________________________

NAME_______________
CLASS_______________
DATE_______________

# *NEUROSPORA* LAB QUESTIONS

1. What does aseptic mean? without contamination

2. What is *Neurospora crassa?* the genus and species name of a filamentous fungus which has been widely used as a model organism for biochemical and genetic research.

3. Why is it important to keep aluminum foil over the mouth of the flask during and after boiling? to prevent contamination from the air.

4. In the Preparation of Medium, Step #2, the instructions state that you are to release some of the medium back into the flask. Is the released medium contaminated at this point? Why or why not? The medium should not be contaminated at this point because the medium was pipetted into a sterile pipette and returned to the sterile flask.

5. Name at least three possibilities for contamination of the medium in this experiment: Answers will vary. Some possibilities are breathing into the flask, touching the tip of the pipette on a nonsterile surface, touching the top of the flask, failing to keep flask covered while pipetting, etc.

6. Do you think the medium will show bacterial contamination after a few days at room temperature? Why or why not? Yes: was possibly contaminated during transfer to pipette. No: everything was sterile and aseptic technique was correctly used.

7. Predict how much or how far the fungus will grow in 24 hours: Answers will vary

8. After two days of growth, how far do you think the fungal growth front will be? Answers will vary.

9. What is the difference between the wild-type and mutant strains? Wild type is the strain that occurs in nature and has orange spores and doesn't exhibit any major mutations. The mutant strains are wild type strains that have undergone a mutation that changes their phenotype. In this case, a mutation has occurred in the biochemical pathway that results in orange spore color causing only white spores or unpigmented spores to be produced.

10. How is the growth of a filamentous fungus different than other cells such as plant, animal or bacterial cells? The filamentous fungus grows by elongating its cells in strands, allowing it to cover a greater area more quickly. Plant, animal and bacterial cells divide into two smaller cells of the same shape. These cells are generally not arranged in filaments, which causes them to be arranged in a concentrated group, not a long filament.

VOCABULARY LIST Define the following words. Be sure to give a complete definition for each word.

1. Hypha- branching or straight filament that is the basic unit of a growing fungus.- Plural: hyphae

2. Aseptic- free of contaminating organisms.

3. Agar-substance used to solidify culture media.

4. Petri dish- dish which is composed of two parts which is used to grow cultures of bacteria or fungi.

5. Race tube-glass or plastic pipette which is filled halfway with solid growth medium and used to conduct fungal "growth races".

6. Growth medium-an agar-based medium which contains a rich supply of nutrients necessary for optimal growth of an organism.

7. Mutant-an organism carrying a gene that has undergone a mutation or a change in genetic code. In these experiments, an example of a mutant would be the albino mutant, which produces white spores instead of the normal wild type orange spores.

8. Wild type- a strain that normally occurs in nature which has not undergone a mutation that changes it radically. In these experiments, Neurospora crassa wild type will produce orange spores its filaments will also appear orange.

9. Contamination- not pure, having other organisms present which are different than the pure culture.

10. Phenotype- the physical expression of a genotype.

# DEMONSTRATION OF CAROTENOID ACTIVITY USING *NEUROSPORA*

This is a very simple and highly interesting way to show how light affects molecules called carotenoids.

Procedure:

1. Pour *Neurospora* growth medium into a small Erlenmeyer flask and allow it to solidify. A good size is a 50ml or 100ml flask with about 20ml or 40ml of medium.

2. Using an inoculating loop, transfer some *Neurospora* to the center of the medium. You should use a wild type strain or one that is known to have some color. You might also want to prepare another flask with an albino mutant to show that it will not change color.

3. Cover immediately and completely with aluminum foil and allow flask to sit at room temperature for 3-4 days.

4. At the beginning of class on the 3rd or 4th day, have students open their flasks and write their observations down. Have students record observations every twenty minutes until the end of class.

5. At the beginning of class the next day, have the students record their final observations. At this time, discuss with the class what they think caused the change and why would this be important to fungi.

*Teacher Notes: Wild-type strains will appear white when the foil is removed from the flask. Placed in light, the fungus should start turning orange.

## TEACHER NOTES

### OBTAINING NEUROSPORA STRAINS:

Neurospora strains can be ordered from the Fungal Genetics Stock Center at a cost of $20 per strain. Once you have a culture, it is very easy to maintain it. You must use the FGSC number which is given below for each strain ordered.

To order, write to::
Kevin McCluskey, PhD
Curator, Fungal Genetics Stock Center
Department of Microbiology
University of Kansas Medical Center
Kansas City, KS 66160-7420

Phone: 913-588-7044
Fax: 913-588-7295
fgsc@kuhub.cc.ukans.edu
http://kumchttp.mc.ukans.edu/research/fgsc/main.html

*Neurospora crassa* strains:

| | Mating type | |
|---|---|---|
| | A | a |
| Albino strains | | |
| al-1 | 4657 | 4658 |
| al-2 | 4659 | 4660 |
| al-3 | 4661 | 4662 |
| Yellow strains | | |
| ylo-1 | 4669 | 4670 |
| ylo-2 | 4671 | 4672 |
| Ropy strains | | |
| ro-4 | 2980 | 2981 |
| Circadian rhythm strains | | |
| frq;bd | 2670 | |
| frq;bd | 4898 | |

All strains used in these experiments are *Neurospora crassa.*

Teacher Options:

1. You may want to prepare race tubes ahead of time and give them to your students and have them inoculate them.

2. You may want to have to students do this entire experiment.

3. You may want to demonstrate aseptic technique before you have the students do it. This is strongly suggested.

4. You might want to prepare petri dishes with *Neurospora* growth medium and let students open the dishes five to ten minutes outdoors. The result will be a variety of colorful molds which grow very quickly and cover the dish in a couple of days.

A Note about Difficulty:

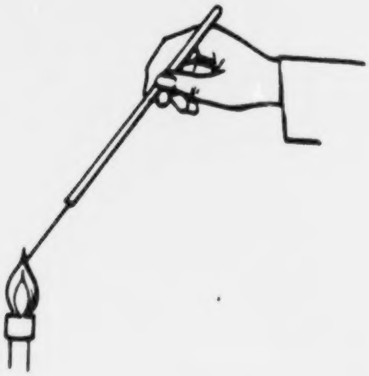
While it is possible to do recombination with *Neurospora*, I feel that this may involve more time and difficulty than a teacher would like to undertake, especially for less advanced classes. I would recommend this only for very advanced classes. If you would like to find out more about this or if you have any other questions, you may call me at school: Nancy McGreger at Stroman High School, Victoria, Texas: (512)- 578-2711 or Dr. Ebbole at Texas A&M.

## Aseptic Technique

1. Wash hands thoroughly with antibacterial soap.

2. Sterilize the tabletop with 10% Clorox solution or 95% ethanol.

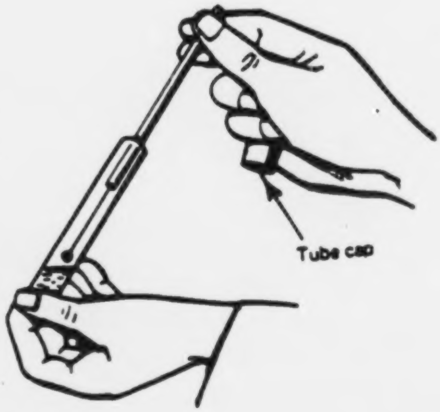
3. Flame inoculating loop with one hand.



Once the loop is flamed, do not allow it to touch anything else but the culture and the agar.
After you have completed the transfer, flame the loop immediately.

4. Open the culture tube or plate and touch the loop to sterile agar to cool the loop.

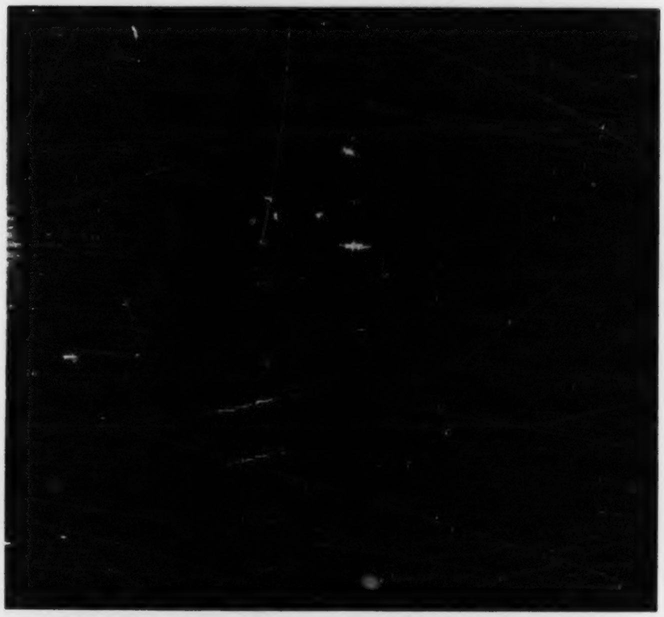
5. Touch the loop to the fungus and withdraw the loop, taking care not to touch the side walls.



6. Replace culture cap or lid.

7. Touch the loop to the agar surface, withdraw the loop and mark place of inoculation. Replace cap of race tube and flame the loop.

**Jennifer Willis**
**Chemistry**
**Per-Service Teacher**



**Texas A&M University**
**Center for Chemical Characterization**
**and Analysis,**
**College Station**
**Dr. E.A. Schweikert, Mentor**

# TTIP
# CURRICULUM IMPLEMENTATION PLAN
## Abstract

**NAME:** Jennifer Willis

**INTERNSHIP:** Texas A & M's Center for Chemical Characterization and Analysis (CCCA)

**SCHOOL:** pre-service teacher

**SUBJECTS :** Chemistry I(H) or Chemistry II

**ACTIVITIES:**

- Mass spectrometry instruction via Powerpoint 4.0
- Mass spectrometry analysis via slides
- group project
- self, group, and peer group evaluation
- optional enrichment activities and advanced organizers

**SUMMARY:** In this unit, a variety of teaching methods are made available to the Chemistry teacher to aid in the instruction of the principles of basic mass spectrometry and time-of-flight mass spectrometry. Students are given the opportunity to work as a team while moving through the six levels of Bloom's Taxonomy.

**RESOURCES:** Dr. Emile A. Schweikert, Center for Chemical Characterization, TAMU, College Station, Texas, 77843-3144.

Edward Funkhouser. Associate Head of Undergraduate Education, Department of Biochemistry and Biophysics, Texas A & M University.

Brian T. Walenta, Project Coordinator, Texas Alliance for Science, Technology, and Mathematics Education, TAMU.

1994 & 1995 Texas Teacher Internship Program Curriculum Implementation Plan Publication.

# Mass Spectrometry: The Adventure

## Introduction:

These lessons have been constructed to provide the teacher with options concerning the instruction of mass spectrometry and time-of-flight mass spectrometry. This unit is designed for Chemistry I (H) or Chemistry II students, depending on the depth of Chemistry taught in each course. This unit should follow a unit/set of lessons pertaining to the molecule, the mole, calculating molecular mass, and defining the charge on a molecule. While some lessons were prepared using Powerpoint 4.0 and Netscape 2.0, lesson notes are provided to assist the instructor without computer/computer software availability. Alternative approaches are given at the beginning of each lesson for the teacher without such equipment.

The overall purpose of this unit is to challenge students to go beyond the state standards established for Chemistry and participate in a unique research experience. Students will develop valuable communication and critical thinking skills while gaining an understanding of what scientists experience daily as they explore the world around them. The unit is designed to build up to a final group project where students are required to utilize the information made available to them on time-of-flight mass spectrometry to simulate an experiment and present their results to their peers. The enrichment activities are optional and given to provide the teacher with flexibility regarding instruction. If the instructor, however, intends to have the students participate in the group project, the material on time-of-flight mass spectrometry or other related information needs to be available to the students. The instructor should provide as many of the options supplied in this unit as possible to assist the students in completing the group project successfully. The time allotted for each lesson will vary depending on the bell schedule. Suggestions for traditional and block schedule are provided with each lesson.

## Goals:

Upon completion of this unit, the student will be able to:

1) understand the basic principles of mass spectrometry and time-of-flight mass spectrometry
2) understand the application of mass spectrometry and time-of-flight mass spectrometry
3) analyze a simple mass spectrum
4) participate in a group project using his/her knowledge on time-of-flight mass spectrometry
5) improve on and utilize current communication skills in a group presentation on time-of-flight mass spectrometry
6) critically evaluate him/herself, his/her group, and a peer group upon completion of the project and presentation

If you would like a copy of the computerized lessons to be run on Powerpoint 4.0, please contact the author at the permanent address listed below:

Jennifer Willis
108 Greenway
Victoria, Texas 77904
512-578-6176

# Mass Spectrometry - The Adventure Part I

(a lesson prepared on Powerpoint 4.0)

## Level:

Chemistry I (H) or Chemistry II

## Suggested Scheduling:

1 traditional bell schedule (50 min)
2/3 block schedule (1 hr 30 min)

## Purpose:

This tutorial is designed to teach the student the basic principles of mass spectrometry and should follow a unit/set of lessons pertaining to the molecule, the mole, calculating molecular mass, and defining the charge on a molecule. The instructor may opt to teach the class as a whole, utilizing the notes of the presentation or set-up the presentation as part of a workstation for the student to learn on his/her own or with his/her group. This lesson is the first of two lessons on mass spectrometry. The second lesson furthers the discussion, focusing on time-of-flight mass spectrometry.

## Objectives:

Upon completion of this lesson, the student will be able to:

1. understand the basic principles governing mass spectrometry
2. understand who uses this process
3. understand what occurs to a sample following injection into a mass spectrometer
4. understand how the ions are separated in mass spectrometry
5. understand how the ions are represented following separation

## Materials:

- an IBM computer with mouse hook connection (if available)
- Powerpoint 4.0 computer software (if available)
- Lesson 1 entitled, "Mass Spectrometry: The Adventure Part I," the computerized Powerpoint 4.0 version or the screen notes of the lesson that follow this page.

## Procedure:

### Computer Option:

The student/teacher will have to load the lesson into the computer from Powerpoint 4.0 into the "slide show." The student will be asked to advance from one screen to the next by clicking on the mouse. The program takes the student step by step through a tutorial covering the objectives stated above.

**Teaching Option:**

The instructor will discuss the objectives of the lesson with the students and proceed through the lesson, utilizing the notes provided (read the screens left to right) to meet the objectives stated above.

## Assessment of Student Achievement:

**Computer Option:**

At the conclusion of this lesson, the student will check his/her own understanding of the material with a short quiz on his/her own paper. The student will then submit his/her answers after correction to receive credit for participating in the tutorial. If a group completes the lesson together, only one set of answers needs to be submitted for credit.

**Teaching Option:**

The instructor may utilize the evaluations given at the end of the presentation to quiz the class on the material.

**Scoring and Reteaching:**

Point values for each question are given with the quiz. Students are encouraged to take notes during the presentation. Students scoring below a 60 are advised to repeat the lesson before advancing to lesson two. Their performance on the quiz provided at the end of the lesson will reflect their understanding of the material and ultimately, affect their performance on the group project.

## Enrichment:

Some enrichment opportunities are as follows:

1. Performing an internet search of "Mass Spectrometry" and reporting on the information made available.
2. Writing a report on Mass Spectrometry, utilizing several resources. Resources might include the internet, a University library, and/or a trip to a mass spectrometry laboratory or research facility.
3. Taking a field trip to a mass spectrometry laboratory and reporting on the findings. An evaluation sheet is provided with this lesson and may be used for this trip and/or any other field trip to a laboratory or research facility. Scheduling the class, as a whole, to go might be more beneficial.

## Mass Spectrometry - The Adventure Part I

(click to advance to the next screen)

**The Plan:** This lesson is the first of two lessons on **Mass Spectrometry**. In this lesson, we will discuss what mass spectrometry comprises. In the second lesson, our discussion will further, focusing on time-of-flight mass spectrometry.

(click to advance to the next screen)

At the conclusion of the lesson, you will check your own understanding of the material you have learned with a short quiz. **Please take notes** along the way, as it will help you to complete the quiz successfully.

(click to advance to the next screen)

**Objectives:**

By the end of this lesson, you will be able to understand:

- the basic principles governing mass spectrometry
- who uses this process
- what occurs to a sample following injection into a mass spectometer
- how the ions are separated in mass spectrometry
- how the ions are represented following separation

(click to advance to the next screen)

Who uses mass spectrometry? All sorts of people all over the world. In fact, here are just a few.

- chemists
- engineers
- doctors
- police
- biologists
- physicists

(click to advance to the next screen)

What is mass spectrometry used for?

**To identify compounds**. Examples of its use are:

- steriod detection
- detection of dioxins in contaminated fish
- determine composition of molecular species in space
- determine specimen age in archaeology
- establish elemental composition of semiconducting materials

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Mass spectrometry is just one of several means of compound analysis that scientists use to identify unknown compounds. Infrared spectrometry, X-ray diffraction, and Nuclear Magnetic Resonance are three other means of compound analysis widely used today.

(click to advance to the next screen)

According to The American Society for Mass Spectrometry's (ASMS) 1995 What is Mass Spectrometry?, mass spectrometry is an analytical method used to identify unknown compounds in quantities as small as 10^-15 gram.

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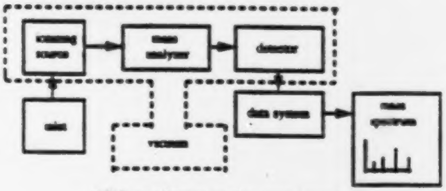
Molecules are converted to ions/charged molecules and their mass is then measured via mass spectrometry. How does this occur? A general mass spectrometry set-up is shown below.



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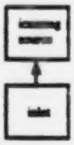
Let's go through the analysis one portion at a time. A sample is injected into the inlet and then ionized by a very powerful source such as a laser. Let's take a look at what happens to the common compound, carbon dioxide.



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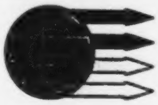
Ionization breaks down the molecule carbon dioxide, CO2, into fragments. Thus, it becomes:



CO2+ CO+ C+ O+

(click to advance to the next screen)

Recall that the positive sign in each fragment/ion has lost an electron. (Exactly how this occurs during ionization remains a mystery.)

Fragments/ions can be negatively charged as well. For our purposes, however, we will always refer to the fragments/ions as positively charged.

(click to advance to the next screen)

Other ionization techniques (besides laser) are:

- Fast Atom Bombardment
- Secondary Ion Mass Spectrometry
- Laser Desorption
- Field Desorption
- Electrospray
- Electron Ionization
- Chemical Ionization

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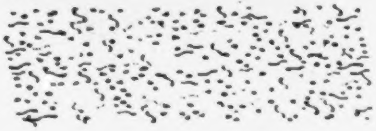
In the first five techniques listed, the sample is vaporized and ionized at the same time. In the last two, the oldest of ionization techniques, the sample is vaporized prior to ionization.



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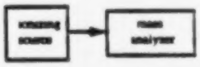
After the sample is in its ionic form, the ions are then sorted according to their mass/charge ratio (m/z) in the analyzer.

Each fragment has its own m/z value i.e. CO2+ has a different m/z value than CO+ or C+ or O+.



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Some mass analyzers in use today are:

- quadropole mass filters
- magnetic/electric sectors
- ion traps
- time-of-flight
- Fourier transform ion cyclotron resonance spectrometer

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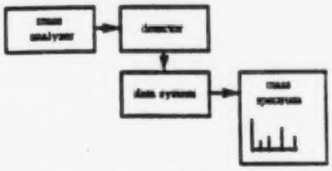
The analyzer then transfers the ions to a detector that generates an electrical signal. that signal is recorded by the data system or computer and prints out a mass spectrum.



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A spectrum is very similiar to a set of fingerprints. Just like fingerprints give help identify who you are, a spectrum helps scientists identify compounds and molecules.

mass
spectrum

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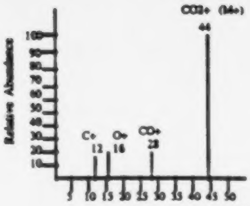
Each peak on the spectrum represents the m/z (mass/charge) ratio for each fragment of the molecule.



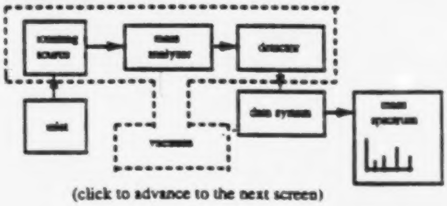
| ion | m/z |
|---|---|
| CO2+ | 44 |
| CO+ | 28 |
| O+ | 16 |
| C+ | 12 |

(click to advance to the next screen)

The fragmentation pattern in the spectrum provides scientists with clues to help them identify compounds present in the sample.

(click to advance to the next screen)

The entire system is kept under vacuum or really low pressure to prevent molecules from colliding with other molecules during the process.



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You may now check your understanding of the material so far. Please take a few moments to answer the questions that follow by yourself and then advance to the next screen to check your answers.

Each question is worth 20 points plus an extra 10 points for the bonus.

(click to advance to the next screen)

## Quiz

1. What is the main use of mass spectrometry?

2. Name two professionals who use mass spectrometry.

3. When a sample is injected into a mass spectrometer, what occurs immediately following the injection?

(click to advance to the next screen)

4. The ions of the molecule are then separated according to their what?

5. The m/z ratio of the ions is represented by what means?

(click to advance to the next screen)

Bonus (+10):
What size samples are analyzed by a mass spectrometer (i.e. big or small)?

That's it for the quiz, now let's check your answers to see how you did!

(click to advance to the next screen)

The **answers** to your quiz are as follows:

1. Mass spectrometry is used to identify unknown compounds.
2. Chemists, engineers, doctors, police, biologists, and physicists.
3. The sample is ionized.
4. Mass/charge or m/z ratio.
5. A mass spectrum displaying a peak for each m/z value.

(click to advance to the next screen)

Bonus: Samples as small as 10^-15 gram.

Your scores will not be recorded unless otherwise specified by your instructor.
They do, however, reflect your understanding of the material and will effect your performance on the final project.

(click to advance to the next screen)

If you scored below a 60, I suggest you repeat this lesson before proceeding to lesson two.
Please correct your answers to this quiz and submit a copy to your instructor for credit on this tutorial (for groups, one is sufficient).

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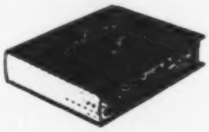
Information for this presentation was taken from The American Society for Mass Spectrometry's 1995 What is Mass Spectrometry?



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This presentation was developed during the summer of 1996 as part of the Texas Teacher Internship Program (TTIP) at Texas A & M with the guidance of TTIP Coordinator Brian T. Walenta.

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Research for this presentation was performed at Texas A & M's Center for Chemical Characterization and Analysis under the supervision of Dr. Emile E. Schweikert, Chemistry Department Chair and Director of the CCCA, and his research group. Members of the group were:

Dr. Michael Van Stipdonk
Dr. Karima Baudin
W. Ricky Ferrell
Jim Blankenship
Shera von Heimburg
Ronny Harris
Vanessa Santiago
Robert English

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Produced and edited by:

Jennifer Willis

You have now completed Lesson 1 of this series on Mass Spectrometry. To continue, please exit this Lesson and open Lesson 2.

copyright 1996

# Mass Spectrometry - The Adventure Part II

(a lesson prepared on Powerpoint 4.0)

## Level:

Chemistry I (H) or Chemistry II

## Suggested Scheduling:

1 traditional bell schedule (50 min)
2/3 block schedule (1 hr 30 min)

## Purpose:

This tutorial is designed to teach the student the basic principles of time-of-flight mass spectrometry and should follow **Mass Spectrometry - The Adventure Part I**. The instructor may opt to teach the class as a whole, utilizing the notes of the presentation or set-up the presentation as part of a workstation for the student to learn on his/her own or with his/her group.

## Objectives:

Upon completion of this lesson, the student will be able to:

1. understand what the term "time-of-flight" indicates
2. understand why 252 Cf is a good ionizing source
3. understand the overall reason for using time-of-flight mass spectrometry over other mass spectrometry techniques
4. understand which fragments/ions will hit the detector first and last

## Materials:

- an IBM computer with mouse hook connection (if available)
- Powerpoint 4.0 computer software (if available)
- Lesson 1 entitled, "Mass Spectrometry: The Adventure Part II," the computerized Powerpoint 4.0 version or the screen notes of the lesson that follow this page.

## Procedure:

### Computer Option:

The student/teacher will have to load the lesson into the computer from Powerpoint 4.0 into the "slide show." The student will be asked to advance from one screen to the next by clicking on the mouse. The program takes the student step by step through a tutorial covering the objectives stated above.

**Teaching Option:**

The instructor will discuss the objectives of the lesson with the students and proceed through the lesson, utilizing the notes provided (read from left to right) to meet the objectives stated above.

## Assessment of Student Achievement:

**Computer Option:**

At the conclusion of this lesson, the student will check his/her own understanding of the material with a short quiz on his/her own paper. The student will then submit his/her answers after correction to receive credit for participating in the tutorial. If a group completes the lesson together, only one set of answers needs to be submitted for credit.

**Teaching Option:**

The instructor may utilize the evaluations given at the end of the presentation to quiz the class on the material.

**Scoring and Reteaching:**

Point values for each question are given with the quiz. Students are encouraged to take notes during the presentation. Students scoring below a 60 are advised to repeat the lesson. Their performance on the quiz provided at the end of the lesson will reflect their understanding of the material and ultimately, affect their performance on the group project.

## Enrichment:

Some enrichment opportunities are as follows:

1. Performing an internet search of "Time-of-Flight Mass Spectrometry" and/or "Plasma Desorption Mass Spectrometry," reporting on the information made available.
2. Writing a report on ToF-MS and/or PDMS, utilizing several resources. Resources might include the internet, a University library, and/or a trip to a mass spectrometry laboratory or research facility.
3. Taking a field trip to a mass spectrometry laboratory and reporting on the findings. An evaluation sheet is provided with this lesson and may be used for this trip and/or any other field trip to a laboratory or research facility. Scheduling the class, as a whole, to go might be more beneficial.

# Mass Spectrometry - The Adventure Part II

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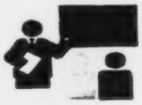
**The Plan:** This lesson is the second of two lessons on **Mass Spectrometry**. In this lesson, we will discuss time-of-flight mass spectrometry.



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At the conclusion of the lesson, you will check your own understanding of the material you have learned with a short quiz. **Please take notes** along the way, as it will help you to complete the quiz successfully.

(click to advance to the next screen)

**Objectives:**

By the end of this lesson, you will be able to understand:

- what the term "time-of-flight" indicates
- why 252 Cf is a good ionizing source
- the overall reason for using time-of-flight mass spectrometry over other mass spectrometry techniques
- which fragments/ions will hit the detector first and last

(click to advance to the next screen)

Thus far, we have learned the basic principles associated with mass spectrometry. Now, we will look at a specific method of mass analysis known as **time-of-flight.**

(click to advance to the next screen)

With other mass analyzers (ion traps, quadropoles, etc...), only one m/z value can be detected at one time. Time-of-flight mass spectrometry is able to give more than one m/z value at the same time.

**That's the advantage! More than one m/z value!**

(click to advance to the next screen)

The overall goal of mass spectrometry is to be able to analyze smaller and smaller samples composed of larger molecules. Time-of-flight has been around since 1974 and is used to analyze larger biomolecules that can not be analyzed by other methods because they are too big.

**Biomolecules of 500,000 to 750,000 amu (atomic mass units) have been analyzed so far!**

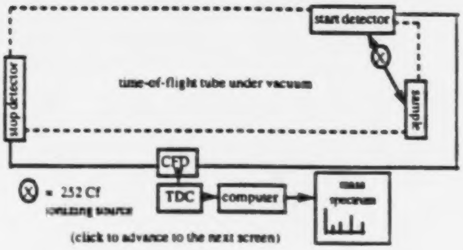
(click to advance to the next screen)

Recall, the amu is 1/12 the mass of a Carbon atom. Calculations show that 1 amu=1.6606 x 10^-24 gram, therefore, the largest biomolecules analyzed weigh between 8.30 x 10^-19 and 1.20 x 10^-18 gram.

**That's still very small!**

(click to advance to the next screen)

The name "time-of-flight" corresponds to the time an ion is in flight and is proportional to the square root of m/z. The instrumentation is set up as follows:


start detector
stop detector
time-of-flight tube under vacuum
sample
CFD
TDC
computer
mass spectrum
⊗ = 252 Cf
ionizing source

(click to advance to the next screen)

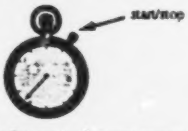
Let's take a look at the set-up one section at a time. First, we will discuss the detectors and one type of ionizing source involved in time-of-flight mass spectrometry.

252 Californium (Cf) is a radioactive isotope of the element Californium that is a type of ionizing source used in time-of-flight mass spectrometry.

⊗ = 252 Cf
ionizing source

(click to advance to the next screen)

This radioactive source is constantly undergoing fission. The detectors are like start and stop buttons on a stop watch. When a 252 Cf source is used, one fission fragment from the 252 Cf will strike the sample to ionize it while another fission fragment is given off in the opposite direction and hits the detector.



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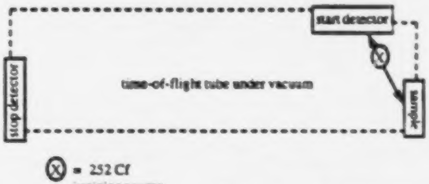
**The constant emission of fission fragments from the radioactive 252 Cf makes it a good ionizing source.** (This is a special kind of ionization known as Plasma Desorption.)


start detector
stop detector
time-of-flight tube under vacuum
sample
⊗ = 252 Cf
ionizing source

(click to advance to the next screen)

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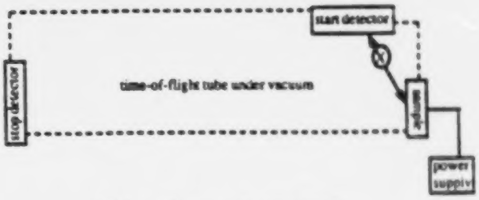
The principle behind time-of-flight is that the ions are being separated according to their different flight times over a given distance. In order for the sample ions to be accelerated and their flight times recorded, however, they have to have a "kick" or be pushed off.

(click to advance to the next screen)

Think of a track runner waiting in his starting block. Unless he pushes off with his foot when the whistle blows, he won't go anywhere!

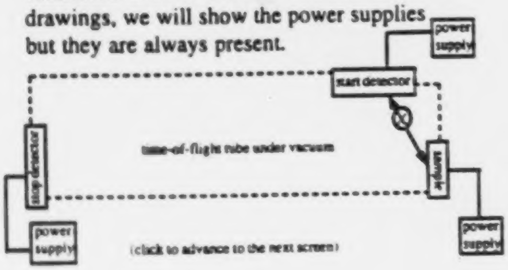
(click to advance to the next screen)

A power supply of approximately 10 kilovolts is hooked up next to the sample to produce the "kick" and push off all of the ions at a constant acceleration.


start detector
stop detector
time-of-flight tube under vacuum
sample
power supply

(click to advance to the next screen)

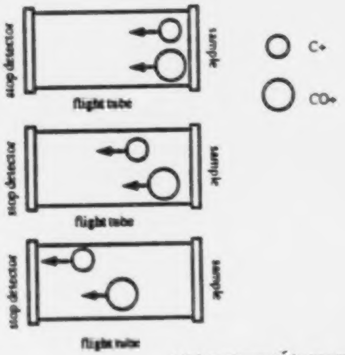
The entire instrument, however, is powered by electronics, thus there is a power supply connected to both detectors as well. In our drawings, we will show the power supplies but they are always present.


power supply
start detector
stop detector
time-of-flight tube under vacuum
sample
power supply
power supply

(click to advance to the next screen)

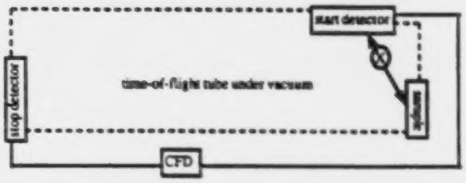
Lighter ions/fragments will reach the stop detector in less time than heavier ones. A lighter ion/fragment will have less mass than a heavier ion/fragment. Using our example of carbon dioxide from Lesson 1, we would expect the lighter ion C+ that has a mass of 12 to reach the stop detector before the heavier fragment CO+ that has a mass of 28.

(click to advance to the next screen)


stop detector
sample
flight tube
C+
CO+
stop detector
sample
flight tube
stop detector
sample
flight tube

(click to advance to the next screen)

The start and stop detectors are connected through the CFD, the Constant Fraction Discriminator, that filters out any unwanted "noise" from the ending spectrum.


start detector
stop detector
time-of-flight tube under vacuum
sample
CFD

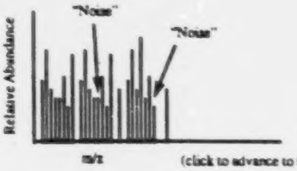
(click to advance to the next screen)

"Noise" is represented by a lot of unnecessary peaks that interfere with the overall analysis and can be due to:

- undetected fluctuations in temperature
- electrical output
- oscillations in pressure
- variations in humidity
- unwarranted instrumental vibrations

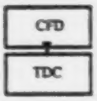
(click to advance to the next screen)

For instance, in this spectrum, it is very difficult to determine what any of the peaks are due to the amount of "noise" present in the spectrum. In fact, "noise" is what keeps scientists busy, as they try to eliminate it as much as possible from their spectra.



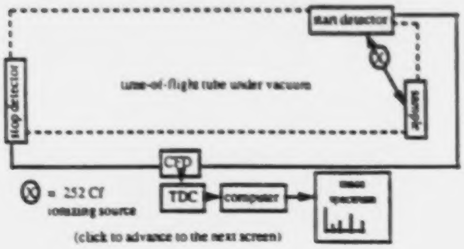
(click to advance to the next screen)

The CFD is then connected to the TDC or time-to-digital converter. The TDC is a very fast stop clock that records the flight times of the ions. (Remember the track race - the detectors are the buttons that the guy pushes to time the runners. The TDC is the actual timing device inside the stop watch.)



(click to advance to the next screen)

The signals are then transferred to a computer or data system and a spectrum given, just the same as in regular mass spectrometry.


start detector
stop detector
time-of-flight tube under vacuum
sample
CFD
= 252 Cf
ionizing source
TDC
computer
mass spectrum

(click to advance to the next screen)

Recall from Lesson 1, the entire system must remain under vacuum to prevent the molecules from colliding. The time-of-flight system mass spectrometer is kept under 10^-6 torr, a very low pressure. That means that almost no air is present in the system - you wouldn't be able to breathe under those conditions!

(click to advance to the next screen)

You may now check your understanding of the material so far. Please take a few moments to answer the questions that follow by yourself and then advance to the next screen to check your answers.

Each question is worth 25 points plus an extra 10 points for the bonus.

(click to advance to the next screen) ☑

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## Quiz

1. The "time-of-flight" of an ion indicates the what?

2. Why is 252 Cf a good ionizing source?

3. What is the advantage of using time-of-flight over any other mass spectrometry technique?

(click to advance to the next screen)

---

4. Will a heavier ion/fragment reach the detector before/after a lighter ion/fragment?

Bonus (+10):

What is the largest mass (in amu's) of a molecule detected by time-of-flight mass spectrometry thus far?

(click to advance to the next screen)

---

The **answers** to your short quiz are as follows:

1. The time an ion remains in flight in the mass spectrometer.
2. It is constantly emitting fission fragments that ionize the sample.
3. More than one m/z value can be generated at one time.
4. After a lighter ion/fragment.

**Bonus:** 750,000 amu

(click to advance to the next screen)

---

Your scores will not be recorded unless otherwise specified by your instructor.

They do, however, reflect your understanding of the material and will effect your performance on the final project.

(click to advance to the next screen)

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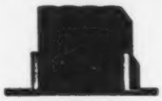
If you scored below a 60, I suggest you repeat this lesson to gain a better understanding of the material.

Please correct your answers to this quiz and submit a copy to your instructor for credit on this tutorial (for groups, one is sufficient).

(click to advance to the next screen)

Information on **mass spectra analysis** can be found in other tutorials. Catherine Fenselau takes you step by step through the analysis of mass spectra, explaining fragmentation patterns and how to use them to identify different compounds. Look for her work on mass spectral interpretation in multimedia form in your local library.



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Information for this presentation was taken from the following:

Robert Cotter's 1988 paper "Plasma-Desorption: Coming of Age" published in The American Chemical Society's Analytical Chemistry, vol. 60, pp. 781-793.

Robert Cotter's 1992 paper "Time-of-Flight Mass Spectrometry for the Structural Analysis of Biological Molecules" published in the American Chemical Society's Analytical Chemistry, vol. 64, pp. 1027-1039.

(click to advance to the next screen)

Whitten, Gailey, and Davis's 1988 General Chemistry with Qualitative Analysis, 3rd edition, published by Saunders College in Chicago, IL, pp. 41-42.

Skoog and Leary's 1992 Principles of Instrumental Analysis, 4th edition, published by Saunders College in Fort Worth, TX, p. 47.

(click to advance to the next screen)

This presentation was developed during the summer of 1996 as part of the Texas Teacher Internship Program (TTIP) at Texas A & M with the guidance of TTIP Coordinator Brian T. Walenta.

(click to advance to the next screen)

Research for this presentation was performed at Texas A & M's Center for Chemical Characterization and Analysis under the supervision of Dr. Emile E. Schweikert, Chemistry Department Chair and Director of the CCCA, and his research group. Members of the group were:

| | |
|---|---|
| Dr. Michael Van Stipdonk | Shera von Heimburg |
| Dr. Karima Baudin | Ronny Harris |
| W. Ricky Ferrell | Vanessa Santiago |
| Jim Blankenship | Robert English |

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Produced and edited by:

Jennifer Willis

You have now completed Lesson 2 of this series on Mass Spectrometry.

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# Mass Spectrum Analysis

(slideshow)

## Level:

Chemistry I (H) or Chemistry II

## Suggested Scheduling:

1 traditional bell schedule (50 min)
2/3 block schedule (1 hr 30 min)

## Purpose:

This tutorial is designed to teach the student how to analyze a mass spectrum. The instructor may opt to teach the class as a whole, utilizing the notes of the presentation or set-up the presentation as part of a workstation for the student to learn on his/her own or with his/her group.

## Objectives:

Upon completion of this lesson, the student will be able to:

1. understand the purpose behind generating a mass spectrum
2. understand and be familiar with common fragmentation patterns that occur in molecules
3. understand what the peaks in a mass spectrum represent
4. identify specific peaks represented in a mass spectrum based on common fragmentation patterns

## Materials:

- Catherine Fenselau's 1973 "Mass Spectral Interpretation File," published by the J. Huley Association in Merion, Pa (check the nearest University library) or the notes for some of the spectra she reviews that follow this plan
- a slide-projector (if utilizing the slideshow)
- "Common Mass Spectrum Fragments" from Paul Young's tutorial on spectroscopy at the University of Illinois, Chicago; found on an internet search on Netscape 2.0 under Murray's Mass Spectrometry Page - click on Mass Spectrometry Resources, Information and Archives, Tutorial: Mass Spectrometry under the heading Education, and then Common Ions and Fragments to pull up the listing (the list is provided with this lesson for your convenience)
- computer with Netscape 2.0 if you choose to locate the "Common Mass Spectrum Fragments" yourself

**Note:** m/z is represented as m/e in these spectra

## Procedure:

The teacher may opt to utilize the slideshow or use the notes of the first two spectra taken from Fenselau's work to teach the material. If the slideshow is used, the instructor will need to load the slides into the projector and play the accompanying audio tape while the students listen to and watch the presentation. (The teacher may opt to set up the projector at a work station for the students as part of this unit. I would recommend this be done based on the learning rate of the students. This material can get very confusing if the students are left to themselves.) The instructor should provide a copy of the "Common Mass Spectrum Fragments" (accompanies this lesson) to each student prior to the presentation to familiarize them with the common fragmentation patterns found in molecules. The instructor should pause and ask the students if they understand the presentation every so often and ask them to refer to the "Common Mass Spectrum Fragments" worksheet during the presentation to identify the various peaks shown in the spectra under analysis.

** Students should be able to identify the peaks in a mass spectrum given the structure of a molecule and the fragmentation patterns, not predict the patterns themselves nor name the name/structure of a molecule - these are higher order skills to be developed at the college level.

## Assessment of Student Achievement:

The quiz that follows the material in this lesson exams the students' knowledge of the material. Each question is worth 25 points, for a total of 75 points. I recommend awarding 25 points to the students for participation during the presentation. A score below 50 on the quiz would suggest that the student does not understand the material well and needs to review his/her notes before moving on with the other activities in this unit, especially the group project.

Whether utilizing the slideshow or the notes from Fenselau's file, ten unknowns are given in Fenselau's presentation to quiz the students on their understanding of the material. Included with this lesson is the unknown spectra acetone. The instructor needs to be familiar with the fragmentation patterns of the unknown to answer student questions. The spectra for acetone could easily be misunderstood for butane if the fragmentation patterns are not noted. Have the students use the common fragmentation patterns provided to identify unknown compounds. Correct identification of the unknown acetone would indicate that the student has a good understanding of the material. Next, provide the students with the name and structure of the unknown molecule and ask them to use the common fragmentation patterns to identify the peaks shown in the spectrum. Identification of the peaks for the unknown, given this added information, would indicate that the student has an average understanding of the material.

## Reteaching Option:

If the students are not able to correctly identify the peaks, review the knowns, identifying the peaks present. Then, analyze the unknown a second time with the students. When the students are comfortable with identifying the fragmentation patterns and peaks on the spectrum, ask them to analyze other unknowns that you provide.

## Enrichment:

Some enrichment opportunities are as follows:

1. Identifying all ten unknowns in Fenselau's presentation or other spectra that the students locate.
2. Presenting the unknown identifications to the class.
3. Extending this material to identify an unknown for a science project, working with a mass spectrometry laboratory.

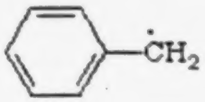
**** I recommend that the instructor come back to the material learned in this unit on mass spectrometry and, in particular, spectral analysis after the students have learned about naming compounds and organic molecules. Ask the students to identify those molecules and compounds used to study fragmentation patterns in this unit i.e. the naming of heptane, cyclohexanol, etc...**

# Common Mass Spectrum Fragments

*Use the **Back Arrow** to return to a spectroscopy problem*

Return to Mass Spectrum Home Page

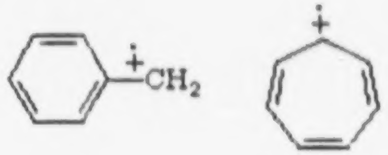
**Commonly Lost Fragments**

| | | |
|---|---|---|
| m-15 | $\cdot CH_3$ | |
| m-17 | $\cdot OH$ | |
| m-26 | $\cdot CN$ | |
| m-28 | $H_2C=CH_2$ | |
| m-29 | $\cdot CH_2CH_3$ | $\cdot CHO$ |
| m-31 | $\cdot OCH_3$ | |
| m-35 | $\cdot Cl$ | |
| m-43 | $CH_3\dot{C}=O$ | |
| m-45 | $\cdot OCH_2CH_3$ | |
| m-91 |  | |

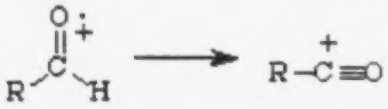
**Common Stable Ions**

m/e = 43 $CH_3-\overset{+}{C}\equiv O$

m/e = 91



m/e = m-1



The lists given above are by no means exhaustive and represents only the simplest and most common fragments seen in the mass spectrum.

*Use the **Back Arrow** to return to a spectroscopy problem*

Return to Mass Spectrum Home Page

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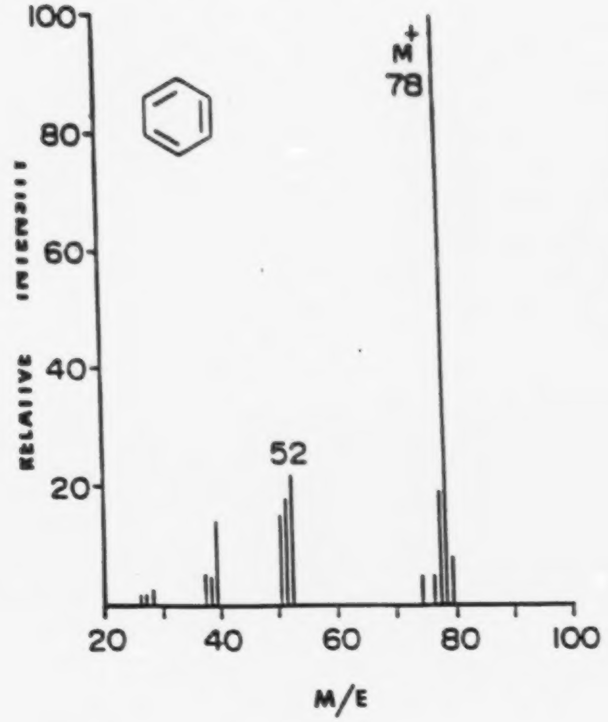
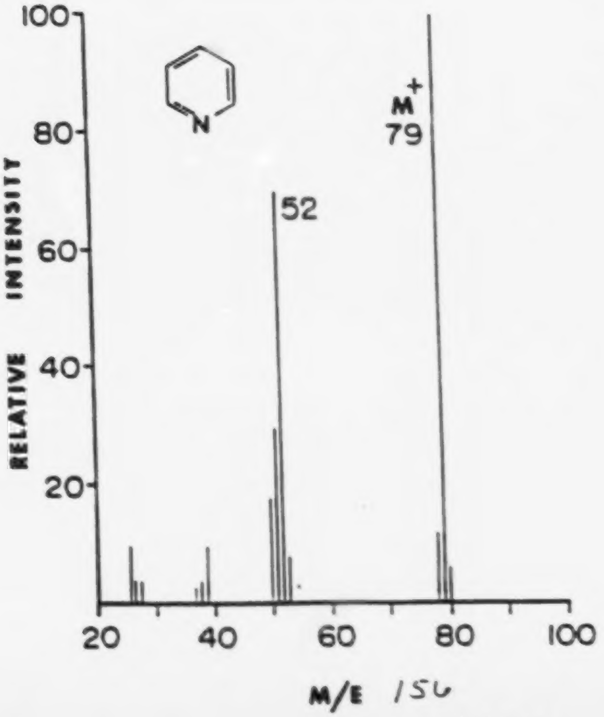


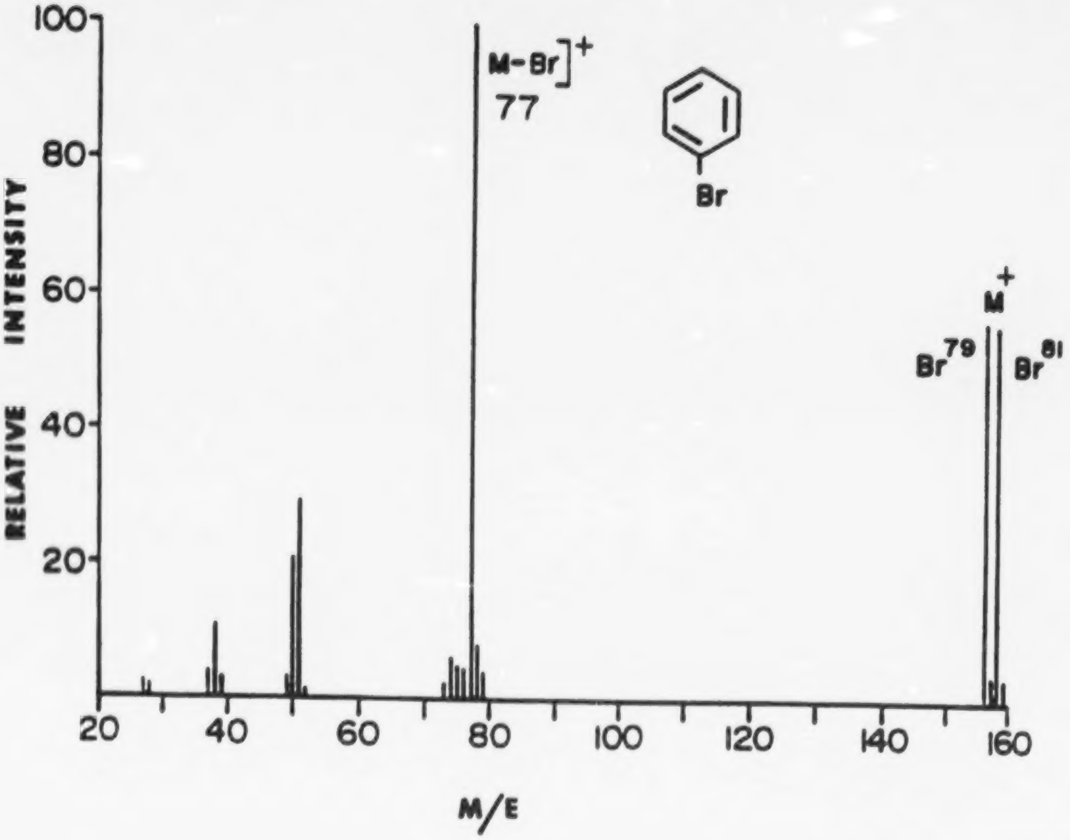
**Benzene**

In a mass spectrum the ions are presented according to the ratio of their mass to charge (m/e). The peak in the spectrum which represents the most abundantly formed ion species is usually plotted with an intensity of 100 %. The intensities of peaks representing all other ions are plotted relative to this. Benzene has a molecular weight of 78 amu. The peak at m/e 78, which represents the molecular ion, is also the base peak, or the most intense peak in the spectrum.



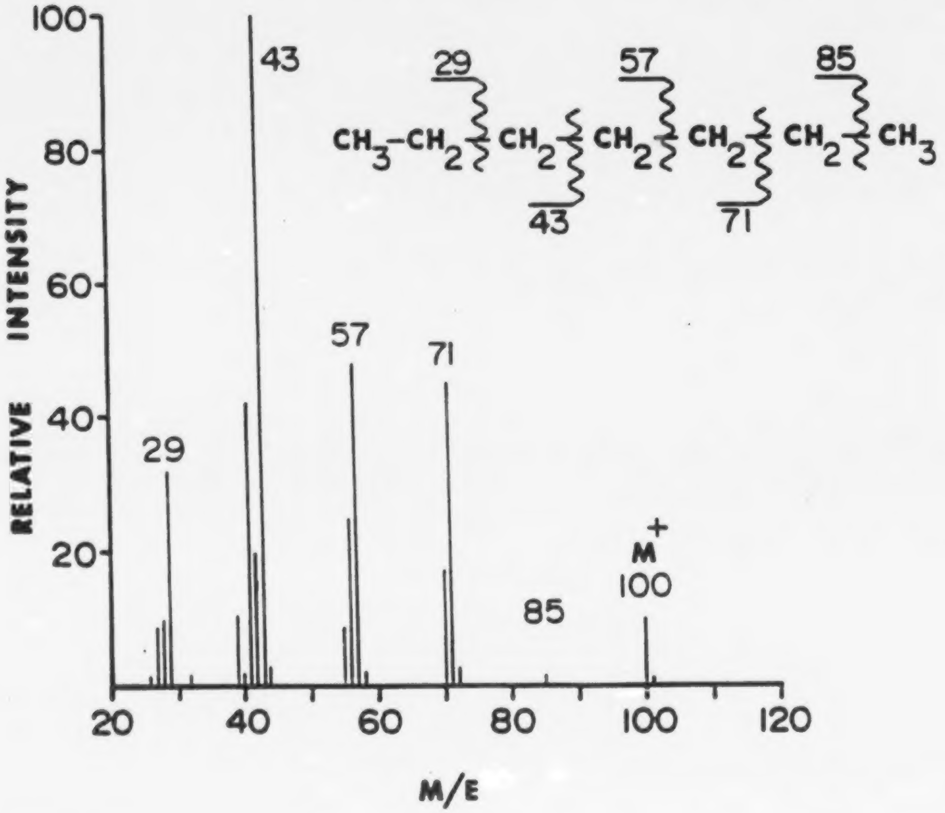
**Pyridine**

The molecular ion peak occurs at m/e 79, and is also the base peak in the spectrum. Molecular weight is usually the most important piece of information which can be obtained from the mass spectrum of an unknown sample. Only compounds which contain odd numbers of nitrogen atoms - pyridine, for example -have molecular weights which occur at odd numbers. Interpretation of a spectrum requires comparison of the mass of each fragment ion to the mass of the molecular ion, and consideration of the mass of the neutral fragment which has been eliminated. The second most intense peak in the spectrum of pyridine occurs at m/e 52, and represents ions formed by the loss of 27 atomic units from the molecular ion. The neutral fragment eliminated is known to be HCN.



Bromobenzene

This spectrum contains two molecular ion peaks which represent ions containing the two isotopes of bromine, $Br^{79}$ and $Br^{81}$. The natural abundances of these isotopes are nearly equal. Mass spectrometry is the best way to measure the abundances of stable isotopes in a molecule.



Heptane

Every C-C bond in this simple hydrocarbon is broken to produce a series of ions 14 mass units apart. In some ions, C-H bonds have been cleaved as well. For the most part you will be interested in the fragmentation characteristic of various functional groups. However, every spectrum of an aliphatic compound will contain some hydrocarbon peaks of the type seen here. The peak occurring one mass unit above the molecular ion peak represents molecules containing one $C^{13}$ atom. The natural abundance of such molecules will be 1.1 percent for every carbon atom present. Thus the molecular ions of mass 101 should be 7.7% as abundant as the molecular ion of mass 100.

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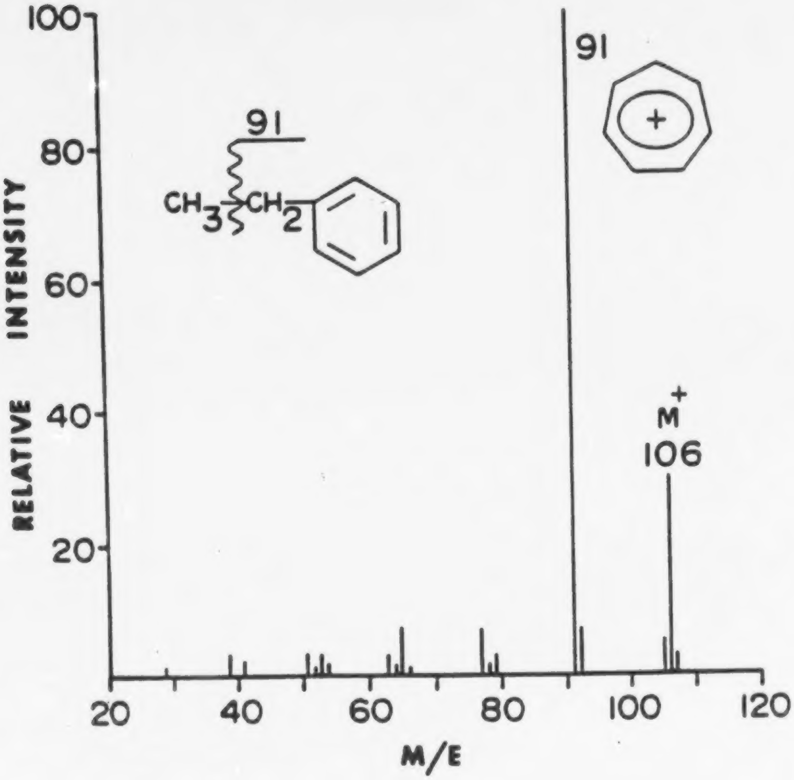
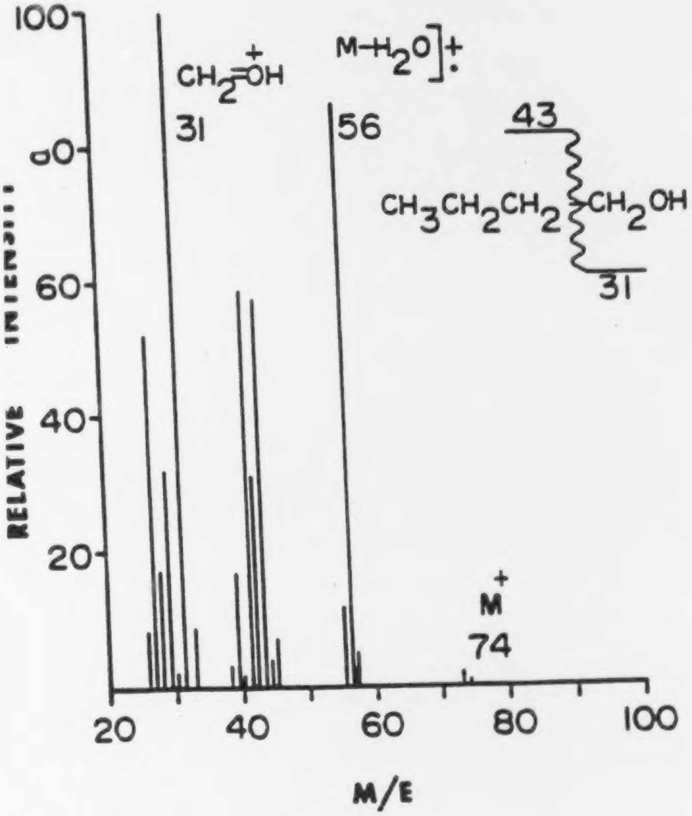


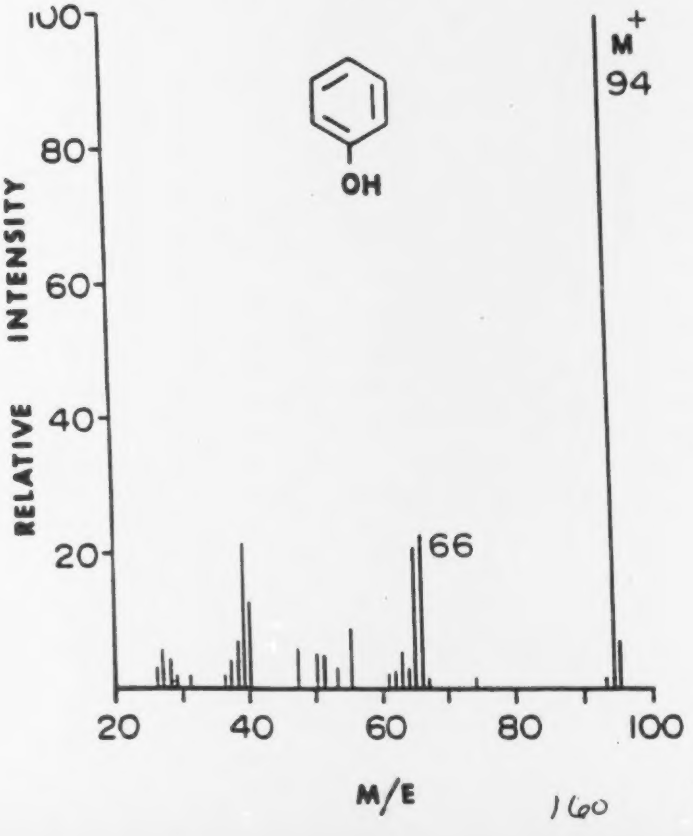
Ethylbenzene

The fragmentation of this aromatic hydrocarbon is not nearly as random as that of heptane. Cleavage occurs in the C-C bond next to the ring, as shown in the figure, and generates abundant ions of mass 91. These ions are considered to have a tropylium structure.



**1-Butanol**

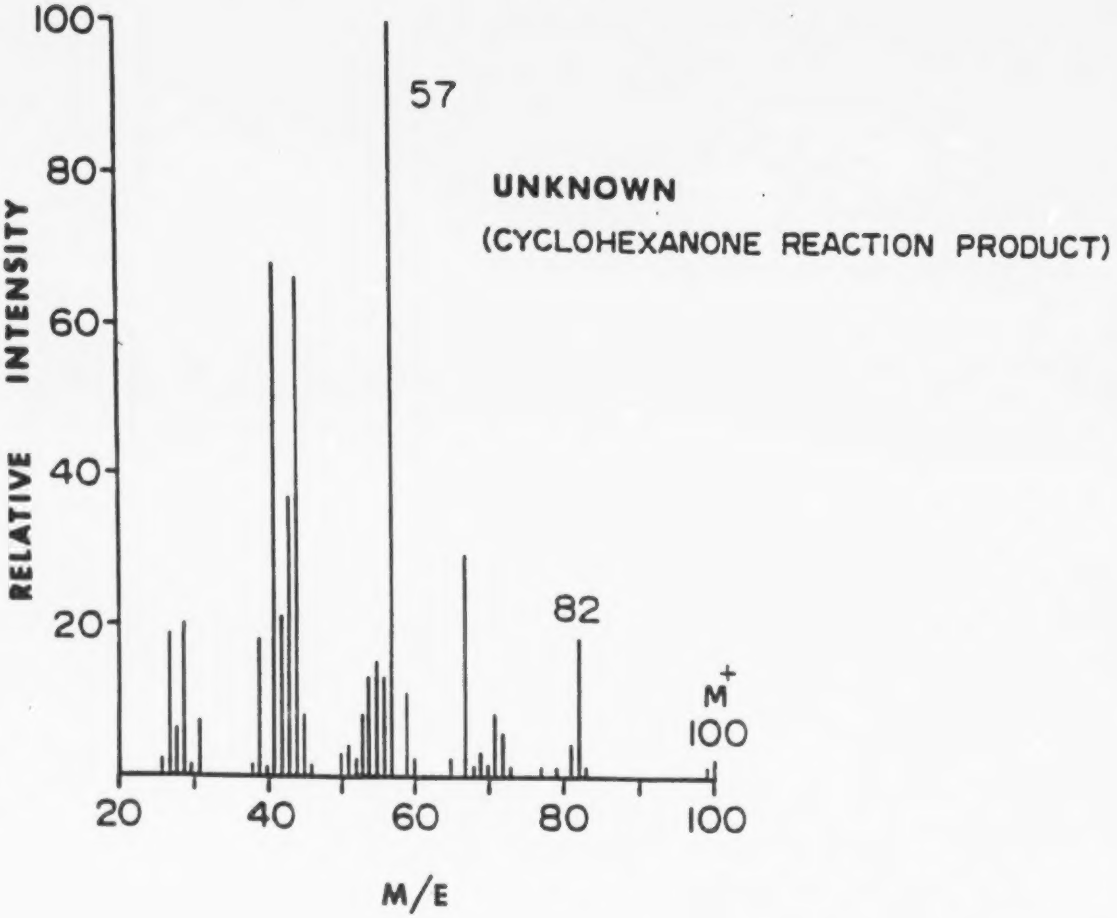
The elimination of H2O from the molecular ion is characteristic of all but the shortest aliphatic alcohols. The abundant ions of mass 31 are formed by scission of the C-C bond next to the hydroxyl group. This may be termed alpha cleavage.



**Phenol**

The molecular ion peak is also the base peak in the mass spectrum of this aromatic compound. Ions of mass 66 are known to be formed by elimination of CO from some of the molecular ions.

Fig. 42



Cyclohexanol

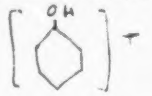
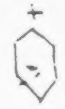
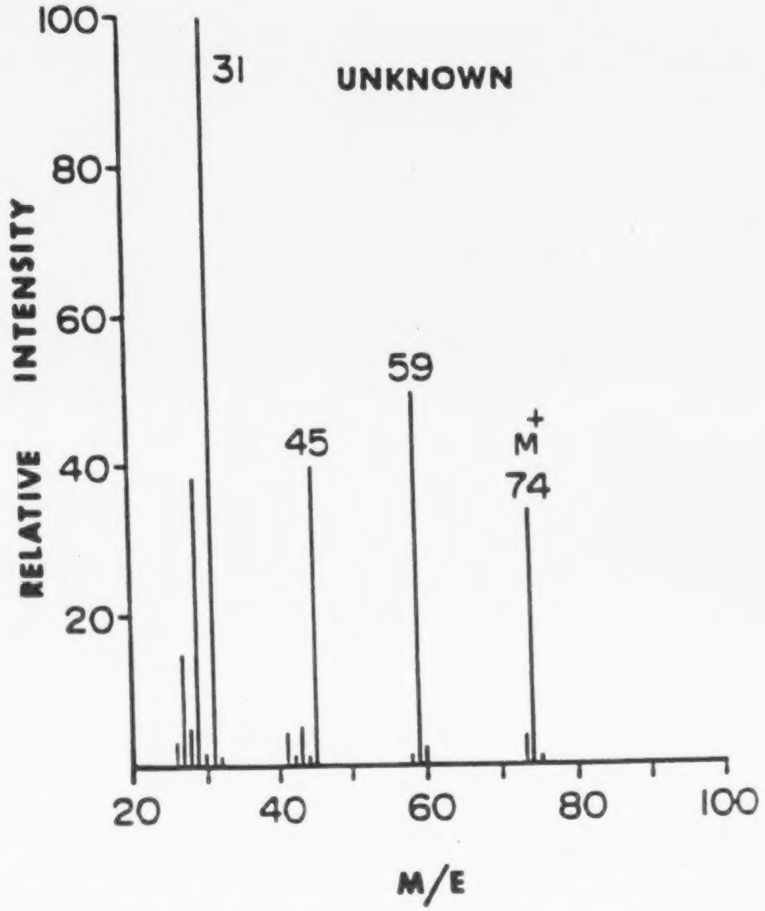
The molecular ion M+ for the molecule is shown at m/z=100 and is depicted structurally as . The peak at m/z=82 is the  fragment and the peak at m/z=57 is the $C_4H_9^+$ fragment.

Fig. 43



**Diethylether**

The molecular ion M+ for the molecule is shown at m/z=74 and is depicted structurally as $\left[CH_3CH_2C\,CH_2CH_3\right]^+$ The peak at m/z=59 is the $CH_3CH_2OCH_2^+$ fragment, the peak at m/z=45 is the $CH_3CH_2C^+$ fragment. and the peak at m/z=31 is the $CH_3C^+$ fragment.

# Advanced Organizer: Research Experience

## Level:

Chemistry I (H) or Chemistry II

## Suggested Scheduling:

1/2 of a traditional bell schedule with optional discussion time (50 min each):
30 min of a block schedule with optional discussion time(1 hr 30 min):

## Purpose:

The purpose of this activity is to familiarize the student with the type of experiences that a research team undergoes when trying to make a break through. This activity will prepare the student for the group project/experiment in this unit.

## Objectives:

Upon completion of this lesson, the student will be able to:

1. make decisions and explain the reasoning behind his/her decisions
2. critically evaluate what he/she learned via the experience
3. compare the experience to one that a research team might undergo

## Materials:

- the worksheet entitled "Research Experience Simulation"

## Procedure:

The instructor will distribute a copy of the worksheet "Research Experience Simulation" to the students and ask the students to respond to the four scenarios provided. After all students have responded, the instructor may choose to utilize the remainder of the period or an additional 10-15 minutes discussing the students' responses to the scenarios.

## Assessment of Student Achievement:

The student's success will be based on his/her ability to answer each question and evaluate his/her responses.

## Reteaching:

In the event that a student does not explain his/her choice to the provided scenarios, the instructor may choose to meet with the student individually and review the scenarios with him/her. Another option may be to team up the student with another student and ask that the two students discuss the scenarios and explain their choices to each other. After the student has had an opportunity to reason out his/her choice, he/she may have the opportunity to explain his/her choices for credit.

## Research Experience Simulation

You are part of a team entering the National Cake Bakers Annual Contest. For months, your team has been developing an innovative recipe for a creamy fudge marble cake. You expect to take top honors in the contest. In order to do so, your team has to prepare, bake, and frost the cake on sight within one hour. Afterwhich, a panel of judges will evaluate your masterpiece. (There's no cheating involved. Each table is watched by an "official timer" i.e. the guy with the stopwatch in his hand brooding over your group.) Read through the following scenarios and answer the questions that follow with at least two sentences with legitimate answers. Please respond to the questions on your own paper and submit the answers for credit.

1. After setting up your booth, you and your team members begin to look for all of the needed ingredients. Your recipe calls for six eggs (remember we're serving quite a few people - judges, competitor, etc...) and you discover that you only have five in the carton. You could (a) send someone to the nearest grocery store which is five miles away and lose valuable time (remember he has to get to his car which is parked about that far away), (b) borrow one from another group, or (c) change the recipe and risk ruining the product?

Pick one option and explain why you chose that one.

2. You've now got the egg situation taken care of and your team begins to combine the needed ingredients into a large mixing bowl. The bowl is part of an electric mixer. After 30 seconds, the mixer begins to make a horrible sputtering sound and quickly dies. Not sure of the cause of the problem, you must choose to (a) send a member to the nearest contest director to have the power outlet checked, (b) have someone begin mixing the large amount of batter by hand, or (c) see if by chance someone will let you borrow their mixer (not very likely)?

Pick one option and explain why you chose that one.

3. OK, the batter is now mixed up and ready to pour it into the cake pans. First, however, someone needs to grease the pans. Your group has always used Butter Flavored Pan to grease the pans. You guessed it! Someone bought the Original Flavored Pam. Do you (a) use it anyway and risk having the cake flavor tainted with, (b) send someone to the same store five miles away, or (c) just use butter to grease the pans?

Pick one option and explain why you chose that one.

4. After 30 minutes, the cake is finally done. The judges will be making their rounds in the next 10 minutes. The only step left is to frost the cake. While the cake was baking, some of your team members prepared the frosting. Whew! Right now, the cake is cooling on a rack. You look for the decorative cake plate you had hoped to set your creation on for judging and discover that it was cracked somewhere along the way. Do you (a) put the cake on the plate and hope that it covers the crack well enough during judging that no-one notices, (b) put the cake on a paper plate and revel in the attitude "Who cares!", or (c) super glue the plate together?

Pick one option and explain why you chose that one.

After all of the problems along the way, the judging is finally over. Much to your surprise, another group, also introducing a new recipe for creamy fudge marble cake, took top honors and your group was given honorable mention.

The experience you have just gone through is very similar to that which a research team experiences when trying to make a breakthrough that has not been made before.

Two final questions:

1. Having been a part of this experience, what have you learned? (5 sentence minimum)

2. What comparisons can you make between this experience and one that a research team might undergo? (5 sentence minimum)

# Time-of-Flight Mass Spectrometry
# Group Project/Experiment

### Level:

Chemistry I (H) or Chemistry II

### Suggested Scheduling:

3 traditional bell schedules (50 min each):
    1 for expt., 1 for preparing presentation, & 1 for presenting and evaluating
2 block schedules (1 hr 30 min):
    1 for expt. and putting together presentation
    1 for finishing up presentation, presenting, and evaluating

### Purpose:

The purpose of this lesson is to provide the student with an opportunity to participate in a group project/experiment using his/her knowledge on time-of-flight mass spectrometry. The lesson should follow an advanced organizer on undergoing a reseach experience. The student will be expected to contribute equally to his/her team to the success of the project. The teams will be required to meet specific guidelines for their project. The student will have an opportunity to improve on and utilize his/her communication skills in a presentation given by the group regarding their project. Each member will be asked to critically evaluate themselves, the group, and one other team. These evaluations are designed to encourage the student to make any necessary corrections in his/her behavior regarding future group assignments.

* The instructor should simulate his/her own ToF apparatus beforehand to determine which materials would work best, are safer to use in his/her classroom, etc...

### Objectives:

Upon completion of this lesson, the student will be able to:

1. understand more fully the principles of time-of-flight mass spectrometry via a hands on time-of-flight mass spectrometry simulation experiment
2. accept/reject his/her team's simulation design and explain why
3. critically evaluate him/herself, his/her group, and one other team's project/expt.

### Materials:

- suggested materials for building the ToF apparatus are listed on the assignment page and may be altered according to those materials available to the instructor; each team will need a stopwatch or second hand to record the time-of-flight
- the assignment entitled "Time-of-Flight Mass Spectrometry Group Project/Experiment"

## Procedure:

Divide the students into teams and give them the assigment several days in advance and instruct them to bring the materials they plan to use (from the list), if they are not provided by the school, the day of the experiment simulation. Explain to the students that they will have to use their notes and all that they know about time-of-flight mass spectrometry to build their apparatus. (an example is attached)

Allott the students time to build their experimental device, perform the experiment, present their project to the class, and submit their evaluations. (See "Suggested Scheduling" above.)

See attached pages for the assignment and evaluations.

## Assessment of Student Achievement:

The assessment will be seen in the student's evaluation of his/herself, his/her group, and his/her peer group. The lesson will be deemed a success if the student has (1) an average understanding of time-of-flight mass spectrometry, (2) has critically thought about his/her experiment, (3) has critically thought about his/her contribution to the experiment, and (4) has critically thought about his/her peers' experiments. Credit for the experiment and evaluations is explained in the assigment. As always, the instructor may modify the point values to his/her class and their needs.

## Reteaching:

This lesson follows a series of lessons regarding mass spectrometry and time-of-flight mass spectrometry. If the student does not appear to understand these concepts well enough after this project, the student may either (1) study some of the material again and be quizzed individually or (2) explain some of the more simple concepts that mass spectrometry is based on i.e. the mole, the molecule, calculating molecular mass, identifying the charge on a molecule, etc...

The instructor should remember that this lesson is part of a unit designed to challenge students to go beyond the state standards established for Chemistry and participate in a unique research experience. Not all of the students participating in this experience may be up to the level expected by the instructor.

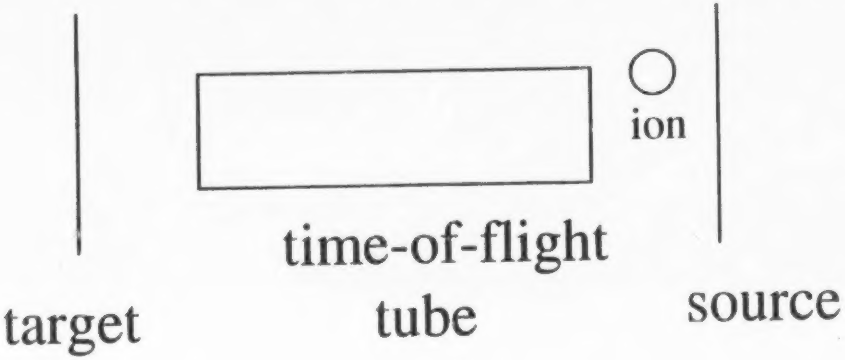
## Enrichment:

Some enrichment opportunities regarding Mass Spectrometry and/or Time-of-flight Mass Spectrometry are as follows:

1. Performing an internet search and reporting on the information made available.
2. Writing a report, utilizing several resources. Resources might include the internet, a University library, and/or a trip to a mass spectrometry laboratory or research facility.
3. Taking a field trip to a mass spectrometry laboratory and reporting on the findings. An evaluation sheet is provided with this lesson and may be used for this trip and/or any other field trip to a laboratory or research facility. Scheduling the class, as a whole, to go might be more beneficial.

# Time-of-flight simulation

Recommendation: Teacher only give out suggestions to those who ask i.e. make them think!



Examples:

source = mouse trap, mini see-saw using tongue depressors & wooden blocks, sling shot
target = cardboard, posterboard, dartboard
ion/fragment = ping-pong balls w/velcro, styrofoam balls, marbles
time-of-flight = toilet paper/paper towel tube, posterboard rolled up tube

# Time-of-Flight Mass Spectrometry
# Group Project/Experiment Assignment

## Purpose:

The purpose of this lesson is to provide you with an opportunity to be a part of a team and use your knowledge on time-of-flight mass spectrometry to help simulate a time-of-flight mass spectrometry experiment. You will be expected to contribute equally to your team to the success of the project. Your team will be required to meet specific guidelines for their project. You will also have an opportunity to improve on and utilize your communication skills in a presentation given by your group regarding your project. Each member of your team will be asked to critically evaluate themselves, your group, and one other team. You will be expected to be honest with yourself regarding the evaluations. Your instructor will be the only person to see your evaluations, unless you choose to show them to a peer.

## Objectives:

By the end of this lesson, you will be able to:

1. understand more fully the principles of time-of-flight mass spectrometry via a hands on time-of-flight mass spectrometry simulation experiment
2. accept/reject your team's simulation design and explain why
3. critically evaluate yourself, your group, and one other team's project/expt.

## Materials:

You may choose from the following list of materials, unless your instructor has said otherwise. Please check with him/her regarding the availability of these materials.

- cardboard
- styrofoam balls- all sizes
- glue
- velcro
- markers
- tongue depressors
- posterboard
- saran wrap
- flashlights
- tape (any kind)
- dart board
- construction paper
- graph paper
- aluminum foil
- toilet paper
- sling shot
- cloth
- stopwatch
- marbles
- toothpicks
- paper-towel tubes
- mouse traps
- chalk
- graph paper
- wooden blocks/ triangles

Your team will need a timing device of some kind. A stopwatch or second hand watch will suffice.

## Requirements/Procedure:

Your team will be required to simulate a time-of-flight mass spectrometry experiment, using only the materials listed(unless otherwise specified by your instructor.) **Yes, you are to build a model of a time-of-flight mass spectrometry apparatus and run an experiment!** Is this going to be easy? Of course not, however, you and your other team members are being asked to combine what you know regarding time-of-flight mass spectrometry to simulate an experiment and meet the following requirements. Each team will be given a molecule/compound name to "perform" the experiment on (ask your instructor). **You will need to design your own source i.e. something to give your ions/fragments a "kick" and/or push them off. You will also only be able to measure the time-of-flight of one ion/fragment at a time.** As this is not an "easy" assignment, please take the next few days to come up with a design for your experiment. Time is of the essence in order for your team to produce a quality product for grading. You are asked to submit a report with all of your information (in a folder/binder - neatly arranged and written) as well as to give a presentation to the class regarding your experiment.

Your team must:

1) Draw and label the fragmentation patterns for your molecule/compound. (You will need to look up the information on your molecules for this part.)

2) Provide data for 5 runs regarding:

    a) the time-of-flight of each anticipated fragment/ion (use stopwatch/ stopwatch)
    b) the m/z ratio for each fragment/ion (use the periodic table; z=1 for our purposes)
    c) graph the time-of-flight of the anticipated ions/fragments plotting the m/z on the x-axis and the time-of-flight on the y-axis (**please color code your fragments/ions to be able to distinguish between them**)

    Please put your data from (a) & (b) in chart form.

3) Draw a diagram of your apparatus. Please do not dispose of your apparatus. You will be asked to show the class what you came up with.

4) Answer the following questions in a brief essay of explanation for each one:

    1. Did the time-of-flights correspond to the anticipated fragmentation patterns i.e. did the lighter ions/fragments reach the "detector" faster? Why or why not?

    2. What materials did you choose for your simulation? Did they work well? Why/why not?

# Mass Spectral Analysis Quiz

Answer the following questions. Each question is worth 25 points.

1) What is the purpose behind generating a mass spectrum?

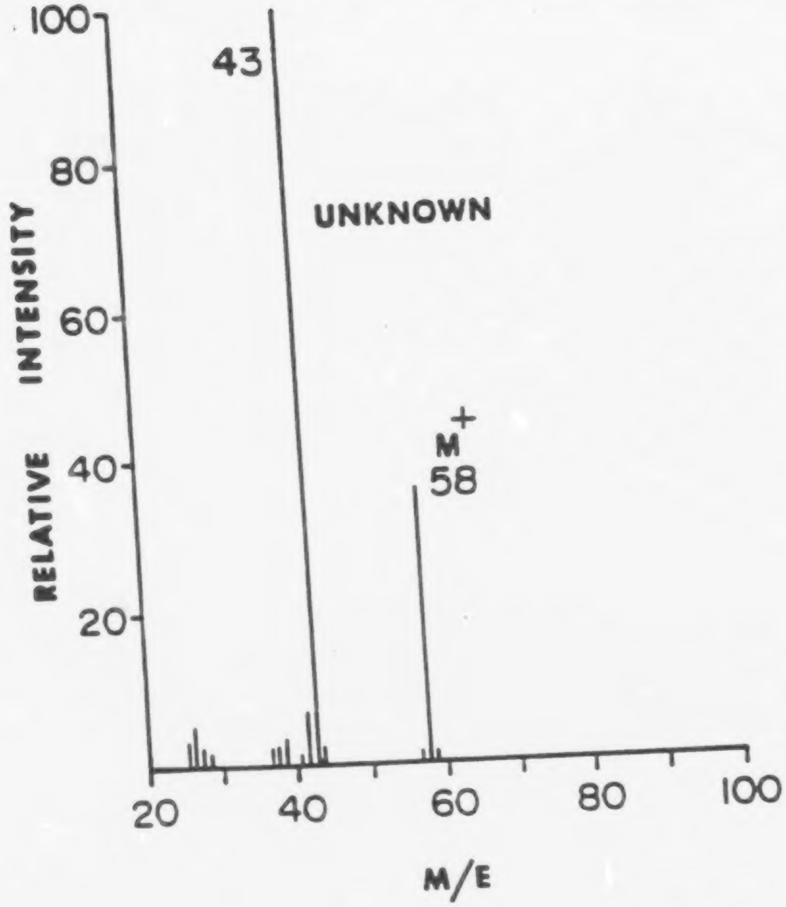
2) List two common fragmentation patterns seen in molecules and their m/z values.

3) What do the peaks in a mass spectrum represent?

**Answers:**

1) To show the m/z values for each fragment/ion in an effort to identify unknown compounds.
2) $CH_3$ @ m/z=15, $CH_3CH_2$ @ m/z=29
3) The m/z values for the common fragmentation patterns of molecules.

Fig. 40



**cetone**

The molecular ion M+ for the molecule is shown at m/z=58 and is depicted tructurally as $\left[CH_3\overset{O}{\overset{\|}{C}}CH_3\right]^+$. The peak at m/z=43 is the $CH_3\overset{O}{\overset{\|}{C}}+$ fragment.

5) Present your project/experiment to the rest of the class as a team, using the data you collected (you may choose to do an average graph of all of your runs to show the class.)

6) Fill out a (1) self-evaluation, (2) group evaluation, and (3) a peer presentation evaluation and submit in your report. There is no need to read each other's evaluations - these evaluations should be kept confidential. Your cooperation is appreciated.

## Point Values:

The following is a list of the point values for each part of this project. Please make note, as your grade will depend on each part.

50 pts. - Building an apparatus and performing the experiment.

20 pts. - Drawing and labeling the fragmentation patterns for your molecule/compound.

30 pts. - Providing data for 5 runs regarding (6 pts each run; each part worth 2 pts):

- a) the time-of-flight of each anticipated fragment/ion
- b) the m/z ratio for each fragment/ion
- c) graph of time-of-flight versus m/z

10 pts. - Data in chart form.

20 pts. - Diagram of your apparatus.

20 pts. - Answering the essay questions. (10 pts each - make sure you answer thoroughly)

50 pts. - Presentation:

- 10 pts. - organization
- 10 pts. - originality
- 5 pts. - team effort
- 10 pts. - well thought out
- 10 pts. - clearly presented
- 5 pts. - reproducibility

60 pts. - Evaluations (20 pts each for completion):

40 pts. - Report submitted in a neat and organized format including all necessary information and a title page listing all group members; due 1 period/block following presentation

**Good luck on this assigment! If you have any questions, don't hesitate to ask the instructor.**

**Name** ____________________
**Group #** ___________

## Self - Evaluation

Please answer the following questions. You are expected to be honest with yourself regarding your responses. Completion of this evaluation will count toward your grade on the group project. Remember that everyone will receive a grade based on their individual participation as well as the work performed by the group as a whole. The instructor will be the only one to see this evaluation unless you show it to someone on your own.

1) What were your responsibilities for this experiment/project?

2) Do you feel that you contributed equally to this experiment? Why/why not?

3) What would you personally have done differently if given the opportunity to re-do this experiment/project?

4) What did you learn from participating in this experience?

**Name** ________________
**Group #** __________

## Group Evaluation

Please answer the following questions. You are expected to be honest with yourself regarding your responses. Completion of this evaluation will count toward your grade on the group project. Remember that everyone will receive a grade based on their individual participation as well as the work performed by the group as a whole. This evaluation will only be seen by the instructor unless you show it to someone on your own.

1) Do you feel that everyone in your group contributed equally to this experiment/project? Why/why not?

2) If given the opportunity to redo this experiment/project, what suggestions do you have for the group?

**Group # evaluated __________**

## Presentation Evaluation (by Instructor)

Your presentation grade is based on my evaluation, however, please review the evaluation performed by your peers as well to make any necessary improvements for future group assigments.

**(Max. points possible)**

_____ (10) organization

_____ (10) originality

_____ (5) team effort i.e. can you tell everyone equally participated

_____ (10) well thought out i.e. how well your team thought out the design for the experiment

_____ (10) clearly presented/explained

_____ (5) reproducibility i.e. based on their information, could you reproduce their experiment

_____ = **Total**

**Comments:**

**Group # evaluated** __________

## Presentation Evaluation (by Peer)

Please designate point values for each category listed below regarding the presentation of the group you are evaluating. You are expected to be honest regarding your responses. Your peers' presentation grade is based on the instructor's evaluation, however, your evaluation may affect their score as well. Completion of this evaluation will count toward your grade on the group project. Remember that everyone will receive a grade based on their individual participation as well as the work performed by the group as a whole.

**(Max. points possible)**

_____ (10) organization

_____ (10) originality

_____ (5) team effort i.e. can you tell everyone equally participated

_____ (10) well thought out i.e. how well they thought out the design for the experiment

_____ (10) clearly presented/explained

_____ (5) reproducibility i.e. based on their information, could you reproduce their experiment

_____ = **Total**

**Comments:**

**Name** ____________________

# Laboratory trip/Research facility Evaluation

This evaluation is worth 20 points total. The remaining 80 points are based on your participation and behavior on the trip. Please be honest and thorough in your responses, as it will help us in scheduling future trips that are geared toward your interests and help you learn the best.

1) What two things at the laboratory peaked your interest during our visit? Explain a little about each. (10 points)

2) What would you have liked to see or see more of during our visit?

## Enrichment Examples

The following sheets are examples of material found on the internet via Netscape 2.01. The library information shown can be found on Texas A & M's home page under the Evans Library heading. Other major universities include their own home pages on the internet where library listings can be accessed.

MS MASS SPECTROMETRY ON THE INTERNET

# Murray's Mass Spectrometry Page

### A Collection of Links to Mass Spectrometry Internet Sites

---

[ **Search** | **Discussion** | Groups | Companies | Resources | Software ]

---

## Sections

Use the text menu bar at the top and bottom of each page for fast navigation.

- **Mass Spectrometry Groups**
  Home pages of mass spectrometry centers and research groups.
- **Mass Spectrometry Companies**
  Web sites for companies that manufacture mass spectrometers.
- **Mass Spectrometry Resources**
  Miscellaneous internet mass spectrometry resources.
- **Mass Spectrometry Software**
  Mass spectrometry utility software: links to programs and other index pages.

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- **Search**
  Search this page, the WWW, or Usenet groups.
- NEW **Discussion**
  Discussion forums for mass spectrometry. Mass spectrometry employment posts, general discussion, and comments about this server.
- NEW **Mass Spectrometry E-Mail Listserver**
  Another experiment in mass spectrometry electronic discussion.
- **Site Information**
  Contains a site submission link and server information and statistics.

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*kmurray@emory.edu*

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# Introduction to Mass Spectrometry (MS)

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## Introduction

Mass spectrometers use the difference in mass-to-charge ratio (m/e) of ionized atoms or molecules to separate them from each other. Mass spectrometry is therefore useful for quantitation of atoms or molecules and also for determining chemical and structural information about molecules. Molecules have distinctive fragmentation patterns that provide structural information to identify structural components.

The general operation of a mass spectrometer is:

1. create gas-phase ions
2. separate the ions in space or time based on their mass-to-charge ratio
3. measure the quantity of ions of each mass-to-charge ratio

The ion separation power of a mass spectrometer is described by the resolution, which is defined as:
R = m / delta m,
where m is the ion mass and delta m is the difference in mass between two resolvable peaks in a mass spectrum. E.g., a mass spectrometer with a resolution of 1000 can resolve an ion with a m/e of 100.0 from an ion with an m/e of 100.1.

---

## Instrumentation

In general a mass spectrometer consists of an ion source, a mass-selective analyzer, and an ion detector. The magnetic-sector, quadrupole, and time-of-flight designs also require extraction and acceleration ion optics to transfer ions from the source region into the mass analyzer. The details of mass analyzer designs are discussed in the individual documents listed below. Basic descriptions of sample introduction/ionization and ion detection are discussed in separate documents on ionization methods and ion detectors, respectively.

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## Mass analyzer designs:

- Fourier-transform MS
- Ion-trap MS
- Magnetic-sector MS
- Quadrupole MS
- Time-of-flight MS

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## Further Information

-

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Science Hypermedia Home Page

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updated 2/23/96

## Dorothy Chavez
## Elementary Education
## Gattis Elementary School, Round Rock ISD

**Texas Parks & Wildlife, Austin**
**Nancy Herron, Mentor**

# CURRICULUM IMPLEMENTATION PLAN

TEACHER: Dorothy Vaughan Chavez, Ph.D.

MENTORS: Bob Murphy and Nancy Herron
Texas Parks and Wildlife, Austin, Texas

GOAL: To give students the opportunity to do research about the ecoregion of Texas in which they live and, as authors of that research, to share the information across Texas via the Internet.

OBJECTIVES:

1. Students will define "ecoregion" and apply its meaning to the region in which they live.
2. Students will use group processing skills to determine the topic of their research:
    - natural resources,
    - cultural resources,
    - natural and cultural resources
    - issue analysis and action plan
3. Students will identify and use all local resources as part of their research.
4. Students will contact "Explore Texas" at Texas Parks and Wildlife (TP&W) and other state agencies, commissions, and departments to request information from the experts in the field of research after doing their basic research.
5. Students will compile a group report to be submitted to "Explore Texas" for publication on the TP&W web pages of the department's Web Site.
6. Students will communicate with students from other schools via the Internet to further share what they have learned.

Due to the nature of this paper, Nancy Herron edited the final copy to meet the requirement of Texas Parks and Wildlife.

* Any items referred to as being in the appendices may be obtained by writing: Texas Parks and Wildlife; Attn: Explore Texas; 4200 Smith School Road, Austin, Texas 78744

# Exploring Texas

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**APPENDICES:**

Resources

TEAN Guide

Web Page Style Guide

# Welcome to Exploring Texas

Your students or youth groups are about to embark on an exciting and memorable learning adventure. At the end of the journey await several unique opportunities – to be authors on the Internet – to create a legacy of Texas resources as seen through their eyes and creativity – and most importantly, to interact with others about the wonders of where they live, their cultural heritage, natural resources surrounding them, or an issue about which they care deeply.

They will, with your help, choose their project focus and decide how they will express what they've learned. We'll place their web pages in a special section on the TP&W Internet site. We'll be using an "ecoregions" theme, with their pages helping to illustrate the diversity of our state. An "ecoregion" defines a part of the state by its most characteristic vegetation, wildlife, geology, and climate. Your group will be creating a body of knowledge about the natural and cultural aspects of their ecoregion.

This manual will guide you through the process of choosing a project and alert you to some of the resources available to you. We recommend that you choose a topic that you're comfortable with but more importantly that your students or youth group are interested in exploring. Kids find work more meaningful if they take part in the decision-making process. Choose together the extent and depth of the project. You may choose a topic or issue based on natural resources, cultural heritage, or the interdependence of people and resources (today, yesterday or tomorrow). Observations or exploratory projects are appropriate for any age; issues are best addressed by fifth graders and older, since objective observations, evaluations and critical-thinking skills will be key.

TP&W will review your topic with you at the onset of your project. TP&W will assist you when possible with materials and identifying informational resources. We'll also provide you with a template for your web pages.

The project has two goals. Those who explore aspects of their environment will have a deeper understanding and appreciation for the diversity of Texas environment and culture. Those researching an issue will develop citizenship skills: the ability to face a difficult issue, responsibly research positions and impacts to the community, and then apply critical thinking skills to evaluate attitudes, recommendations, or action plans.

Before you begin, read the following background information. Keep in mind the goal of helping prepare our youth to understand their world, and to become "environmentally literate."

# Environmental Literacy

We think of "literacy" as the ability to understand and effectively use new information based on previously mastered skills. One can face new information or dilemmas, make observations based on what's known, question for more information, evaluate the quality of that information, and apply critical thinking skills to cope, formulate opinions or create action plans.

Environmental literacy describes the ability to understand and effectively participate in decision-making that affects natural and cultural resources – not only how we live today, but the quality of life for tomorrow.

The need for our youth, tomorrow's decision-makers, to be environmentally literate is compelling. Texas is an amazingly diverse state facing daunting challenges in the next decades.

Currently, 18.2 million people live in this state with a projection of over 30 million by the year 2030. Eighty percent (80%) of our population lives in metropolitan areas. Of that percentage, almost 67% of all Texans live in nine metropolitan areas.

We're concentrating more people in urban areas, depleting natural habitat and minimizing contact with nature. Additionally, families and communities are striving for ways to maintain or reinvest in their cultural heritage to connect today's ever-changing world with the roots of their past.

Lifestyle choices, legislation, and management of both private and public lands play a key role in conservation and preservation. However, the future of resources relies increasingly on the shoulders of our citizens. Of its 266,807 square miles, Texas has a total of only about 3% public lands. The stewardship of Texas is truly in the hands of private landowners.

Educating the public about conservation and management of natural and cultural resources continually emerges as part of the answer to preserving the interests of today's and future generations.

For guidance, we may turn to an international effort addressing mutual concerns for conservation. The United Nations convened several conferences that brought representatives from many countries to address the state of the world's environment. The following definition of **environmental education** came out of the 1970 conference in Stockholm.

*Environmental education is a process of developing a world population that is aware of and concerned about the total environment and its associated problems, and which has the knowledge, skills, attitudes, motivation and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones. (UNESCO, 1978)*

UNESCO held the First Intergovernmental Conference on Environmental Education, the most notable, in Tbilisi, Georgia, of the former U.S.S.R. Referred to as the Tbilisi Declaration, the document set forth goals, objectives, and guiding principles to provide a common beacon and common ground to unite the efforts of environmental educators around the world. The conference provided a foundation for the development of future programs (UNESCO, 1977; Engleson, 1991)

## The Tbilisi Declaration: Guiding Principles of Environmental Education

Environmental education should:

1. Consider the environment in its totality -- natural and cultural, historical, moral, aesthetic;
2. Be a continuous lifelong process, beginning at the preschool level and continuing through all formal and nonformal stages;
3. Be interdisciplinary in its approach, drawing on the specific content of each discipline in making possible a holistic and balanced perspective;
4. Examine major environmental issues from local, national, regional, and international points of view so that students receive insights into environmental conditions in other geographical areas;
5. **Focus on current and potential environmental situations,** while taking into account the historical perspective;
6. **Promote the value and necessity of local, national and international cooperation** in the prevention and solution of environmental operations;
7. Explicitly **consider environmental aspects in plans** for development and growth;
8. Enable **learners to have a role in planning their learning experiences and provide an opportunity for making decisions and accepting their consequences;**
9. **Relate environmental sensitivity, knowledge, problem-solving skills, and values clarification to every age,** but with special **emphasis on environmental sensitivity** to the learner's own community **in early years**;
10. Help learners **discover the symptoms and real causes** of environmental problems;
11. Emphasize the **complexity of environmental problems** and thus need to **develop critical thinking and problem solving skills;**
12. Utilize **diverse learning environments** and a broad **array of educational approaches** to teaching and or learning about and from the environment, with due stress on practical activities and **first-hand experience.**

Being actively involved in this process creates a lifetime memory — make it fun and

Effective environmental education develops an environmentally literate citizenry. Effective environmental education guides not what to think, but how to think environmentally, that is, in terms of the "whole" -- recognizing the interdependence of the social, economic, political, and natural influences. An environmentally literate person gains awareness and knowledge, learns to gather and to the best of their ability assess new information, and applies critical thinking skills to decision-making and individual action.

The Guiding Principles from the Tbilisi Declaration clarifies the goal of environmental literacy. Achieving this goal, however, follows a series of subgoals, illustrated in figure 1. This lifelong process leads to a citizen choosing positive environmental behavior throughout life. As the table illustrates, the stages of Perceptual Awareness, Knowledge, Environmental Ethics, Citizen Action Skills, and Citizen Action Experience are developmental and overlapping. Although not a strict model, you may want to compare your project's goal in terms of the age of your youth and a subgoal.

Figure 2 illustrates how these subgoals lead to choosing positive environmental behavior.

The project you choose will contribute toward one or more stages of development toward environmental literacy. You may think of the project as helping provide awareness of resources or heritage; gaining knowledge or insight; exploring or expressing environmental ethics, learning citizen action skills; or enacting a citizen action experience (such as presenting a well-researched issue to a local governing board for consideration).

Figure 1: Wisconsin Curriculum Model for Environmental Education

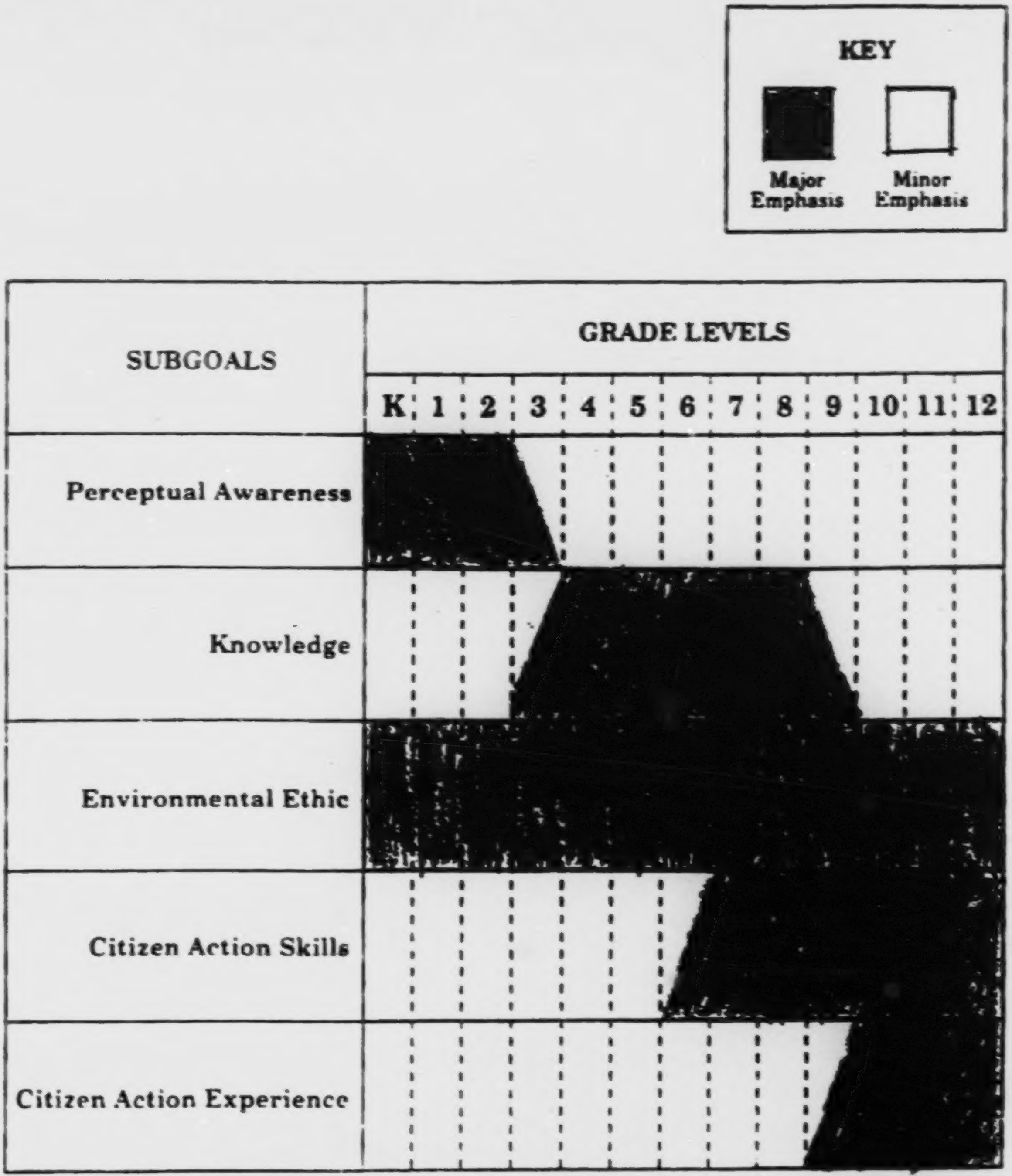
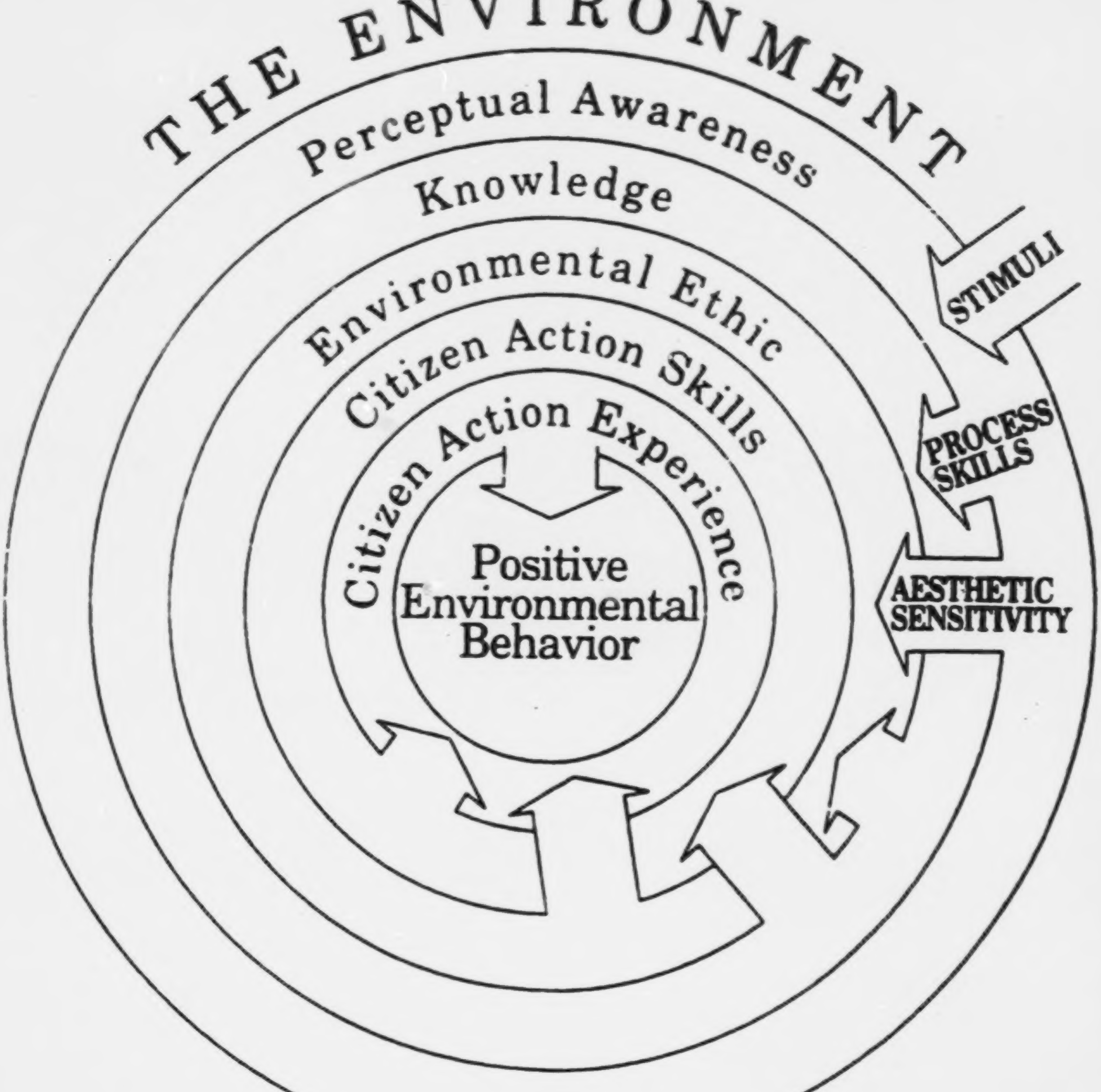


Figure 2: Teaching for Positive Environmental Behavior


THE ENVIRONMENT
Perceptual Awareness
Knowledge
Environmental Ethic
Citizen Action Skills
Citizen Action Experience
Positive Environmental Behavior
STIMULI
PROCESS SKILLS
AESTHETIC SENSITIVITY

# Looking at Natural Resources

Whether in urban, rural, or suburban communities, we are surrounded by nature in some form. Learning to notice the pieces of nature around us happens not by accident, but by deliberate and caring guidance. Learning to understand the sense of ecosystems, the dependence of species and elements upon each other, takes even greater patience and guidance. It's a process of discovery and appreciation that may begin with one piece but ends in the remarkable world of pieces that truly work together.

Your group may begin a discovery of their backyards, a community or state park, a roadside, or some special place. Observations and accurate records or impressions will help the rest of us know what and who lives in your ecosystem.

Some groups may choose to identify an **environmental problem**, caused either by nature or by humans. They may tackle an **environmental issue**, the conflict that arises from how people view problems. (J. R. Gardella, *Environmental Education Curriculum Inventory*, School of Education, Northern Kentucky University, 1993) Investigations of issues, looking at all sides, choosing an action plan, and participating in a citizenship experience can be very rewarding.

To help understand issues and discuss the impact of behavior and decision making on the total environment, we've listed below some basic principles of "ecosystems." Don't worry about mastering all these principles. You may want to refer to some of these ideas, principles, and laws after your investigation, and see if they fit.

A. First **Principle of Ecosystems:**
   All elements needed for life are part of a natural ecosystem. Recycling of wastes sustains the resources in that system.

B. Second **Principle of Ecosystems:**
   Solar energy, which is abundant and nonpolluting, sustains natural ecosystems. All life on the earth's surface is dependent on the sun's energy for survival.

C. Third **Principle of Ecosystems:**
   The producer level of the food pyramid can support the largest population. Plants support the largest populations, whether people or other living things.

D. Principle **of Population Change:**
   Populations increase to the fullest of their potential until they meet with resistance from the environment, which holds the population in balance. For example, predatory birds keep rat populations from exploding.

E. **Principle of Ecosystem Stability**
   Maintaining species diversity provides ecosystem stability. Disease or environmental problems are less likely to adversely affect large parts of the ecosystem if there's great diversity of plant and animal species.

F. Principle **of Species Survival**
   Species survival depends on maintaining genetic diversity and on minimizing change within the species.

G. Law **of Limiting Factors**
   Living things operate within a range of factors required for life. If even one of the factors drops below the lower limit or rises above the upper limit, then the organism feels the effects. When the amount of water in the human body fluctuates above or below the limits of the optimal range for that factor, the human body feels stress that ultimately affects growth, reproduction, and survival.

H. First **Law of Thermodynamics**

Energy cannot be created or destroyed but it can be converted from one form to another.

I. Second **Law of Thermodynamics**

In any energy change the amount of usable energy decreases because of the inevitable loss of heat.

J. Principles **of the Human Component in Ecosystems**

Humans use ecosystems to meet their basic needs and desires.
Humans are dominant in their ecosystems.
Ecosystems affect humans.

(Nebel, 1990; Engleson, 1991)

These brief statements have power in terms of the decisions that humans make about their interactions with the environment. Here is a glimpse of how some of them work.

The sun drives life on earth. The radiant energy that enters our atmosphere is necessary for photosynthesis -- the source of all of plant food. As a byproduct of that process, plants put oxygen into the air and take out carbon dioxide. Change in our environment that interferes with the amount of radiant energy that reaches the earth's surface changes the living and nonliving components of the earth. The potential for harnessing the energy of the sun to fuel human needs is highly desirable because of its abundance and nonpolluting quality.

Consider the action of throwing something away. There really isn't an "Away." The object or substance goes somewhere. What are the impacts of placing these objects or substances in that place? How may be deal with the "away" place more effectively?.

How much water does the earth have for drinking? You may have learned that the earth contains about 30% freshwater and 70% saltwater. This doesn't translate to 30% drinkable water, however. Ice caps, glaciers, and sources inaccessible to humans contain approximately 29% of the freshwater. Humans have only 1% available. The most critical issue to maintaining a sustainable environment today centers on water. What role will your community play in the availability of fresh water?

As you look at the area around you, refer to these principles and laws. If you wonder if any of them directly involves your project, let that become part of the research. You may achieve a new and better understanding of the how the earth works.

# Looking at Cultural Heritage

Culture – your history, your way of life, your values and beliefs – all shape your living environment. Attitudes and heritage guide the character of your community today and set the direction for tomorrow. The richness of a people is reflected in its expressions of culture, through social structure, religion, arts, industry, justice, economy and government. And as much as people rely on natural resources for survival, those same resources are impacted greatly by people. Understanding the history of human interaction with natural resources provides an additional insight into a culture.

How do you investigate cultural heritage today? Oral and written history. Architecture. Museums. Historic sites. Clothing. Music. Art. Examining patterns of community and economic growth – or lack of it. Getting to understand the creative expressions and lifestyle choices of a people. Each thread weaves together into the fabric of culture.

People and artifacts each have a story to tell. In some cases, families pass down the artifacts and stories from one generation to another and they remain within families. Other times, the community becomes the keeper of these treasurers as collections and writings fill libraries and museums. The past comes to life and gives meaning when one can visualize, smell, hear, and sometimes taste the elements of earlier times (trying recipes of one's ancestors, for example).

The search for cultural roots reaches back to the first humans who came onto this land. Archeologists study these ancient peoples through the artifacts and the remnants of the structures that they left behind, like tools, campsites, and villages. By carefully excavating the cultural remains of these ancient native Americans, we can understand how they lived and what they believed in. The remains of one of the earliest inhabitants of what is now Texas were found in the Leander, Texas area on December 29, 1982. The excavation of the Wilson Leonard Site uncovered the burial remains of a 20 to 30 year old woman thought to have lived about 10,100 years ago. From those early Native Americans developed many of the tribes found living here by the Spanish. Following the 200 years of occupation by Spain and later Mexico, Stephen F. Austin brought the early Anglo-American settlers into Texas, beginning a continuing influx of people that forever reshaped history.

Is Texas truly a "melting pot" of culture, customs, and beliefs from around the world? How has one culture been affected by surrounding cultures? What efforts are being made to preserve cultural heritage, or blend with others?

Who are your local legends are heroes? Why do they remain a part of the folklore of your community?

Why have certain cultures moved on the land and stayed? What resources did they find that held them here? How have they impacted resources and how has the land impacted their culture? Natural resources and cultural resources remain interdependent – and a fascinating study.

# Texas Ecoregions

Diversity defines Texas. From coastal waters to desert mountains, Texas holds a plethora of plants, wildlife, and people! One way to illustrate Texas' "biodiversity" is to think of Texas in terms of ecoregions.

Biologists have divided Texas into regions according to several different criteria, based on plant and animal communities as well as topography, geology, soils, and climate. We've chosen a delineation of eleven natural regions to frame the children's study projects.

To familiarize you with ecoregions, we've included excerpts from a program guide developed at TP&W entitled "Exploring Texas Ecoregions." The guide includes more information as well as learning activities especially suited for investigated rare and threatened plants and animals. The "Resources" section of this manual gives information on how to order these and other materials.

As you reflect on interplay of nature and culture, a picture should be forming in your mind about the importance of helping our youth become environmentally literate citizens who will be managing these vital resources.

# Background Information

The organization of Texas into ecoregions or natural regions enables us to inform students about the diverse areas of Texas in an distinct way. By studying the similarities and differences of the various natural regions, students gain a practical and relevant perspective concerning how nature (rainfall, geology, plants and animals) and humans throughout history have shaped the Texas we know today.

Due to its size and geographic location, Texas is unique among states. Covering 266,807 sq. miles, 15 of the 50 states could fit within its borders. A large area of land will usually have a great deal of variation in climate and landscapes, factors influencing habitat diversity. The state has impressive topographic diversity, including 91 mountain peaks that are a mile or more high. Our geographic location is also important in that eastern habitats meet western ones and southern subtropical habitats meet northern temperate ones.

The natural regions of Texas look different from one another, both in terms of the living aspects (plant and animal communities) and the non-living attributes (topography, geology, soils). Texas is divided into the following eleven natural regions:

1. Pineywoods
2. Oak Woods and Prairies
3. Blackland Prairies
4. Gulf Coast Prairies and Marshes
5. Coastal Sand Plains
6. South Texas Brush Country
7. Edwards Plateau
8. Llano Uplift
9. Rolling Plains
10. High Plains
11. Trans Pecos

The accompanying table entitled Features of the Natural Regions of Texas highlights the unique features of each ecoregion, such as size, topography, rainfall, soil types, predominant vegetation, native plant communities, and rare plants and animals.

It may be convenient to group some ecoregions in order to satisfy a 7 or 10 day schedule. The brackets on the list above suggest one way to group the natural regions for study. An interdisciplinary approach may be used by teaching the science portion of the unit in parallel with social studies, integrating the cultural aspects and geography of the regions into the social studies curriculum.

The following is a brief description of each of the ecoregions of Texas.

## Region 1: Pineywoods

Rolling terrain covered with pines and oaks, and rich bottomlands with tall hardwoods, characterize the forests of the east Texas Pineywoods. This region is part of a much larger area of pine-hardwood forest that extends into Louisiana, Arkansas, and Oklahoma.

The average annual rainfall of 36 to 50 inches is fairly uniformly distributed throughout the year, and humidity and temperatures are typically high. The soils of the region are generally acidic and mostly pale to dark gray sands or sandy loams. Elevations range from 200 to 500 feet above sea level.

The Pineywoods region can be described as pine and pine-hardwood forests with scattered areas of cropland, planted pastures, and native pastures. Timber and cattle production are important industries in the region. Farms and ranches are relatively small in size compared to the state average.

Longleaf pine forests once dominated the southeastern part of the Pineywoods. A few pockets of longleaf pine may still be seen today. Mixed pine-oak forests occur to the west and north of the longleaf pine area. Dominant trees include loblolly pine, blackjack oak, and post oak. Hardwood forests of sweetgum, magnolia, tupelo, elm, and ash occur in the lowlands. Swamps are common and are most outstanding in the southern part of the pine-oak forest.

## Region 2: Oak Woods and Prairies

The Oak Woods and Prairies region is a transitional area for many plants and animals whose ranges extend northward into the Great Plains or eastward into the forests. This region, sometimes called the Cross-Timbers, was named by early settlers, who found belts of oak forest crossing strips of prairie grassland.

Average annual rainfall averages 28 to 40 inches per year. May or June usually brings a peak in monthly rainfall. Upland soils are light colored, acidic sandy loam or sands. Bottomland soils may be light brown to dark gray and acidic with textures ranging from sandy loams to clays. The landscape of the region is gently rolling to hilly and elevations range from 300 to 800 feet above sea level.

The region can be described as oak savannah, where patches of oak woodland are interspersed with grassland. Cattle ranching is the major agricultural industry in the Oak Woods and Prairies. Introduced grasses such as bermudagrass are grazed along with forage crops and native grasslands.

## Region 3: Blackland Prairies

The Blackland Prairies region is named for the deep, fertile black soils that characterize the area. Blackland Prairie soils once supported a tallgrass prairie dominated by tall-growing grasses such as big bluestem, little bluestem, indiangrass, and switchgrass. Because of the fertile soils, much of the original prairie has been plowed to produce food and forage crops.

The average annual rainfall ranges from 28 to 40 inches. May is the peak rainfall month for the northern end of the region; however, the south-central part has a fairly uniform rainfall distribution throughout the year. Typically, soils are uniformly dark-colored alkaline clays, often referred to as "black gumbo," interspersed with some gray acidic sandy loams. The landscape is gently rolling to nearly level, and elevations range from 300 to 800 feet above sea level.

Crop production and cattle ranching are the primary agricultural industries.

## Region 4: Gulf Coast Prairies and Marshes

The Gulf Coast Prairies and Marshes region is a nearly level, slowly drained plain less than 150 feet in elevation, dissected by streams and rivers flowing into the Gulf of Mexico. The region includes barrier islands along the coast, salt grass marshes surrounding bays and estuaries, remnant tallgrass prairies, oak parklands and oak mottes scattered along the coast, and tall woodlands in the river bottomlands.

Average annual rainfall varies from 30 to 50 inches per year distributed fairly uniformly throughout the year. The growing season is usually more than 300 days, with high humidity and warm temperatures. Soils are acidic sands and sandy loams, with clays occurring primarily in the river bottoms.

Native vegetation consists of tallgrass prairies and live oak woodlands. Brush species such as mesquite and acacias are more common now than in the past. Although much of the native habitat has been lost to agriculture and urbanization, the region still provides important habitat for migratory birds and spawning areas for fish and shrimp.

## Region 5: Coastal Sand Plains

The Coastal Sand Plains is fairly level with elevations less than 150 feet above sea level. Average annual rainfall is 24 to 28 inches per year and the soils are primarily windblown sands. The vegetation can be described as tallgrass prairie with live oak woodlands, mesquite savannah, and salt marshes. Woody vegetation is more extensive now than in pre-settlement times.

Most of this region is grazed by cattle. In the past, the Coastal Sand Plains were called the "Wild Horse Prairie" because of the large herds of feral horses roaming here in the 19th century.

## Region 6: South Texas Brush Country

The South Texas Brush Country is characterized by plains of thorny shrubs and trees and scattered patches of palms and subtropical woodlands in the Rio Grande Valley. The plains were once covered with open grasslands and a scattering of trees, and the valley woodlands were once more extensive. Today, the primary vegetation consists of thorny brush such as mesquite, acacia, and prickly pear mixed with areas of grassland.

The average annual rainfall of 20 to 32 inches increases from west to east. Average monthly rainfall is lowest during winter, and highest during spring (May or June) and fall (September). Summer temperatures are high, with very high evaporation rates. Soils of the region are alkaline to slightly acidic clays and clay loams. The deeper soils support taller brush, such as mesquite and spiny hackberry, whereas short, dense brush characterizes the shallow caliche soils.

Although many land changes have occurred in this region, the Brush Country remains rich in wildlife and a haven for many rare species of plants and animals. It is home for semi-tropical species that occur in Mexico, grassland species that range northward, and desert species commonly found in the Trans-Pecos.

Livestock grazing and crop production are the principal agricultural land uses.

## Region 7: Edwards Plateau

The Edwards Plateau region comprises an area of central Texas commonly known as the Texas Hill Country. It is a land of many springs, stony hills, and steep canyons. The region is home to a whole host of rare plants and animals found nowhere else on earth.

Average annual rainfall ranges from 15 to 34 inches. Rainfall is highest in May or June and September. Soils of the Edwards Plateau are usually shallow with a variety of surface textures. They are underlain by limestone. Elevations range from slightly less than 100 feet to over 3,000 feet above sea level. Several river systems dissect the surface, creating a rough and well-drained landscape.

The limestone of the Edward's Plateau is honeycombed with thousands of caves. Beneath the eastern edge of the Plateau lies a hidden world of underground lakes known as the Edwards Aquifer. This precious water resource also is home to a number of curious creatures, such as the blind salamander.

Today, the Edwards Plateau is characterized by grasslands, juniper/oak woodlands, and plateau live oak or mesquite savannah. Open grasslands and savannahs were more common in pre-settlement times than they are today. Ranching is the primary agricultural industry in the region.

## Region 8: Llano Uplift

The Llano Uplift is also known as the central mineral region. Although surrounded by the Edwards Plateau region, the Llano Uplift is distinguished by its unique geology. Home to some of the oldest rocks in Texas, the central mineral region contains unique minerals and rock formations. The region is characterized by large granite domes, such as Enchanted Rock near Fredericksburg.

Rainfall averages about 24 to 32 inches per year, peaking in May or June and September. The landscape is rolling to hilly and elevation range from 825 to 2,250 feet above sea level. Soils are predominantly coarse textured sands, produced from weathered granite over thousands of years.

Native vegetation consists of oak-hickory or oak-juniper woodlands, mesquite-mixed brush savannah, and grasslands. Open grassland and savannah were once more common than they are today. Ranching is the predominant agricultural industry.

## Region 9: Rolling Plains

Several Texas rivers begin in the gently rolling hills and broad flats of the Rolling Plains. These rivers and their numerous tributaries are responsible for the rolling character of the land. The rivers have cut canyons that shelter some plants and animals typical of the Rocky Mountains.

Average annual rainfall is 20 to 28 inches, with peaks in May and September. A summer dry period with high temperatures and high evaporation rates is typical. Soils vary from coarse sands along outwash terraces adjacent to streams, to tight clays and shales. Soil reaction is neutral to slightly alkaline. Elevations vary from 800 to 3,000 feet above sea level.

The original prairie grasslands included tall and mid-grasses such as bluestems and gramas. Buffalo grass and other shortgrasses have increased under heavy, uncontrolled grazing. Mesquite is a common invader on all soils. Much of the Rolling Plains today can be described as a mesquite-shortgrass savannah. Stream floodplains are dominated by various hardwood species, and juniper is common on steep slopes along rivers.

Steep slopes, cliffs, and canyons occurring just below the edge of the High Plains Caprock comprise the Escarpment Breaks area of the Rolling Plains. The Breaks are an ecotone or transition zone between the High Plains grasslands and the mesquite savannah of the Rolling Plains. Crop and livestock production are the major agricultural industries in this region.

## Region 10: High Plains

The High Plains region, together with the Rolling Plains, comprise the southern end of the Great Plains of the central United States. The High Plains is a relatively level high plateau, separated from the Rolling Plains by the Caprock Escarpment. Elevations range from 3,000 to 4,500 feet above sea level.

Average annual rainfall is 15 to 22 inches. Rainfall is lowest in winter and mid-summer and highest in April or May and September or October. Extended droughts have occurred here several times this century. Surface texture of soils ranges from clays on hardland sites in the north to sands in the southern portion of the region. Caliche generally underlies these surface soils at depths of two to five feet.

Native vegetation of the High Plains is shortgrass prairie dominated by buffalo grass. Although historically a grassland, mesquite and yucca have invaded parts of the region. Shinnery oak and sand sage are common invaders on sandy lands, and juniper has spread from the breaks onto the plains in some areas.

Immense herds of buffalo and pronghorn antelope once thundered across vast prairies of blue grama and buffalo grass. Today, the plains are mostly irrigated cropland and the native vegetation includes more mesquite and juniper. Although much of the shortgrass prairie and the vast prairie dog towns are gone, large flocks of wintering waterfowl still come to the playa lakes (shallow, round depressions which spot the surface, sometimes covering more than 40 acres).

## Region 11: Trans Pecos

The Trans Pecos is perhaps the most complex of all the regions. It occupies the extreme western part of the state eastward generally to the Pecos River. This is a region of diverse habitats and vegetation, varying from the desert valleys and plateaus to wooded mountain slopes. Elevations range from 2,500 feet to more than 8,749 feet at Guadalupe Peak. Even the mountain ranges vary greatly in the environments they offer for plant and animal life. Some are characterized by volcanic rocks, others by limestone.

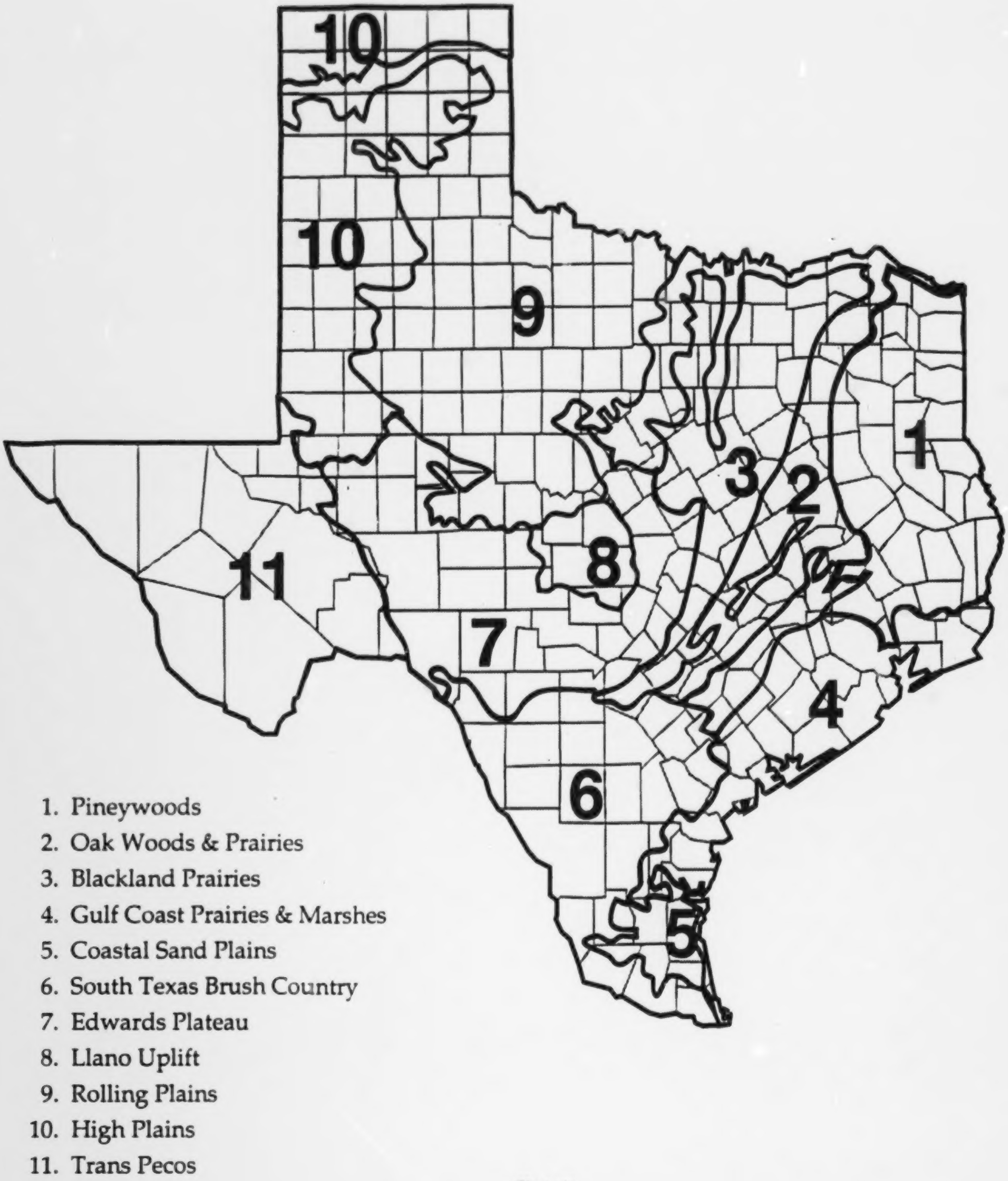
Over most of the area average annual rainfall is less than 12 inches, but varies greatly from year to year and from lower to higher elevations. July and August are usually the higher rainfall months. Mountain outwash materials have formed the soils of the Trans Pecos. Surface textures and profile characteristics are varied. Soil reaction is generally alkaline.

Due to the diversity of soils and elevations, many vegetation types exist in the region. The principal plant communities are creosote-tarbush desert scrub, desert grassland, yucca and juniper savannahs, and montane forests of pinon pine and oak.

The various subregions reflect the diversity of the Trans Pecos. The Sand Hills area consists of shin oak and mesquite on wind-blown dunes. Flat-topped mesas and plateaus are intersected by steep-walled canyons and dry washes that comprise the Stockton Plateau. Soils with high salt content and gypsum dunes are typical of the Salt Basin area. The Desert Scrub subregion is an area of low rainfall and rapid drainage. Creosotebush flats with yucca, lechuguilla, and various small-leafed plants are common. The Desert Grassland area occurs in the central part of the region and is characterized by deeper soils with high clay content. Finally, the Mountain Ranges have higher rainfall and woody vegetation such as junipers, oaks, pinon pine, ponderosa pine, and Douglas fir.

Ranching is the primary industry in the Trans Pecos region.

# Eco Regions of Texas



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| Region | Size (sq. mile) | Topography* | Rainfall (in./year) | Predominant Vegetation | Rare Plants and Habitat | Rare Animals and Habitat |
|---|---|---|---|---|---|---|
| 1. Piney Woods | 23,500 | Gently rolling to hilly forested land | 36-50 | Pine, oak, and other hardwood forests | Texas Trailing Phlox<br>Deep sandy soils of long-leaf pine woodlands<br>White Bladderpod<br>Natural openings of pine-oak woodlands | Red-cockaded Woodpecker<br>Pinewoods with widely-spaced, large, mature pine trees<br>Bald Eagle<br>*Breeding* - In Texas, along river systems or lakeshores with large, tall trees. Breeding populations occur in the eastern half of Texas<br>*Wintering* - Mostly near large lakes and reservoirs. Wintering eagles occur in suitable habitat throughout Texas. |
| 2. Oak Woods and Prairies | 19,500 | Gently rolling to hilly | 28-40 | Oak and hickory woodlands; tall grass prairies | Large-fruited sand verbena<br>Openings within oak woodland on deep sands<br>Navasota ladies-tresses<br>Openings and drainages in post oak woodlands | Houston Toad<br>Pine/oak woodland or savannah on deep, sandy soils |
| 3. Blackland Prairies | 25,500 | Gently rolling to nearly level | 28-40 | Tall grass prairies; mesquite, cedar elm, sugarberry | Tall Grass Prairie plant community has become rare in the Blacklands Region | |
| 4. Gulf Coast Prairies and Marshes | 21,000 | Nearly level | 30-50 | Grasses; tallgrass prairies; live oak woodlands; some mesquite, and acacias | Prairie Dawn<br>Poorly drained, sparsely vegetated areas in open grasslands<br>Slender Rush Pea/South<br>Texas Ambrosia<br>Grasslands or mesquite invaded grasslands | Attwater's Prairie Chicken<br>Tall grass coastal prairie<br>Eastern Brown Pelican<br>Offshore islands, spoil islands, mudbanks<br>Eskimo Curlew<br>Migrates through the grasslands from the Arctic tundra to Pampas grasslands of Argentina<br>Piping Plover<br>Winters along Gulf Coast; tidal mud flats, sandflats, or algal flats<br>Whooping Crane<br>Winters on Texas Gulf Coast; marshes and sandflats of Aransas National Wildlife Refuge and nearby areas |

| Region | Size (sq. mile) | Topography* | Rainfall (in./year) | Predomin Vegetation | Rare Plants and Habitats | Rare Animals and Habitat |
|---|---|---|---|---|---|---|
| 5. Coastal Sand Plains | 4,000 | Fairly level to undulating | 24-28 | Tall grass prairie, live oak woodlands, mesquite savannah | Blacklace Cactus<br>Grasslands or mesquite invaded grasslands | |
| 6. South Texas Brush Country | 28,000 | Level to rolling | 20-32 | Thorny brush including mesquite, acacia, prickly pear, and some grassland areas | Ashy Dogweed<br>Mesquite grassland openings of thorny shrublands on deep, sandy soils<br>Johnston's Frankenia<br>Rocky hillsides or saline clay loam flats within openings of thorny shrublands<br>Star Cactus<br>Openings of thorny shrublands on rocky clay loam soils<br>Texas Ayenia<br>Subtropical woodlands on alluvial deposits on flood plains and terraces of the Rio Grande<br>Walkers Manioc<br>Openings of thorny shrublands on sandy loam soils | Jaguarundi and Ocelot<br>Dense, thorny, low brush<br>Interior Least Tern<br>Bare sand, shell, and gravel beaches, and bars and islands, associated with reservoirs along the Rio Grande |
| 7. Edwards Plateau | 31,000 | Flat to rolling to steep (referred to as the Texas Hill Country) | 15-34 | Shortgrass grasslands, juniper shrubs and oak-juniper forest, mesquite | Texas Snowbells<br>Limestone edges or cliff faces along perennial streams<br>Texas Wild-rice<br>San Marcos River; clear, constant temperature, spring-fed water<br>Tobusch Fishhook Cactus<br>Ashe juniper/oak rangelands on rocky alkaline soils | Black-capped Vireo<br>Semi-open rangelands with a diversity of low growing shrubs<br>Golden-cheeked Warbler<br>Mature woodlands of oaks and Ashe Juniper<br>Edwards Aquifer Species *(San Marcos Salamander, Texas Blind Salamander, San Marcos Gambusia, Fountain Darter)*<br>Spring fed waters of the San Marcos and Comal rivers in Central Texas<br>Clear Creek Gambusia<br>Spring fed headwaters of Clear Creek, a tributary of the San Saba River<br>Karst Invertebrates *(Bee Creek Cave Harvestman, Bone Cave Harvestman, Tooth Cave Pseudoscorpion, Tooth Cave Spider, Tooth Cave Ground Beetle, Kretschmarr Cave Mold Beetle, Coffin Cave Mold Beetle)*<br>Limestone caves, sinkholes & fractures |

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| Region | Size (sq. mile) | Topography* | Rainfall (in./year) | Predominant Vegetation | Rare Plants and Habitat | Rare Animals and Habitat |
|---|---|---|---|---|---|---|
| 8. Llano Uplift | 5,000 | Rolling to hilly | 24-32 | Oak-hickory woodlands; some mesquite juniper brush and grassland | Rock Quillwort<br>Wet weather pools on granite outcrops<br>Basin Bellflower<br>Gravelly or sandy soils | Black-capped Vireo |
| 9. Rolling Plains | 43,500 | Gently rolling to rough and dissected | 20-28 | Originally mid-sized grasses; now mixed with other grasses; invaded by mesquite and junipers; and hardwoods along and near streams | Texas Poppy-mallow<br>Within grasslands or open oak/mesquite woodlands, usually on deep sands | Interior Least Tern *(see region 6)*<br>Along the Canadian and Red Rivers; bare sand & gravel beaches, sandbars<br>Concho Water Snake<br>Free flowing streams over rocks, shallow rifles, and rocks or crevices along banks & shorelines |
| 10. High Plains | 34,500 | Fairly level | 15-22 | Short grasses; mesquite and yucca in some areas, oak and juniper in others | Native shortgrass prairies and their associated plant and animal life has become rare in the High Plains. | |
| 11. Trans Pecos | 38,000 | Diverse, from valley floors to hills to plateaus to mountains | <10-18 | Gradient from dry to wetter with increasing elevation: Desert shrubland and succulent shrubland, grassland, oak-juniper-pinyon woodlands; evergreen forests | Bunched cory cactus<br>Rocky slopes, ledges and flats in the Chihuahuan Desert on limestone<br>Chisos hedgehog cactus<br>Open shrublands on gravelly flat alluvial fan deposits<br>Davis Green Pitaya<br>Rocky hillsides of novaculite (a particular kind of rock) outcrops with sparse vegetation<br>Hinkley's oak<br>Found along arid limestone slopes at mid-elevations in Chihuahuan Desert<br>Nellie cory cactus<br>Dry, rocky limestone outcrops, on slopes in mountains of Chihuahuan Desert<br>Sneed pincushion cactus<br>Dry, rocky limestone outcrops on slopes in mountains of Chihuahuan Desert<br>Little Aguja pondweed<br>Known to occur only within quiet seepage pools in Little Aguja Creek in the Davis Mountains<br>Lloyd's mariposa cactus<br>In full sun on limestone outcrops or rocky, alkaline soils on slopes or mesas<br>Terlingua Creek cat's eye<br>Barren, dry, gypseous clay or chalky shales on low rounded hills and slopes with sparse vegetation | Greater Long-nosed Bat<br>High desert regions of Big Bend National Park<br>Mexican Spotted Owl<br>Canyon woodlands in mountain ranges of West Texas<br>Desert Spring Fishes *(Comanche Springs Pupfish, Leon Springs Pupfish, Pecos Gambusia, Big Bend Gambusia)*<br>Spring-fed desert wetlands and streams |

* Although most of Texas is located on flat plains, there are substantial mountains in the Trans-Pecos region of far West Texas. The highest point in the state is Guadalupe Peak at 8,749 feet above sea level. Sea level is the lowest elevation in Texas and can be found in all coastal counties. Elevation naturally rises from east to west and south to north.

## The Curriculum Connection

Fitting new projects into existing curriculum can be a challenge. Science and / or social studies are natural fits. Having to express what they've learned involves language arts skills. Other applications will emerge as you look through your essential knowledge and skills. This project then offers practical applications to your students' developing skills, making learning more meaningful.

When facing TAAS preparation, consider using the project to enhance those objectives. Along with those practice books used to prepare the students, some of those objectives may be taught or reinforced through the work in this project.

From the natural resources perspective, the process skills found in science apply easily. Students can observe, predict, hypothesize, classify, measure, interpret, make inferences, and draw conclusions from the data. If approached from the scientific inquiry method, the young scientists go through the steps using those process skills. Any grade level that teaches units on life science or earth science has a link to natural resources.

Teachers can involve several other areas of the curriculum. Math skills have a place in collecting data, especially when gathering quantitative information, measuring, and producing any charts or graphs. Language arts skills enable students to read for a purpose, gather supporting details, look for cause and effect, and write a report telling about the research and results.

Teaching students to keep a nature journal can improve their observation skills by causing them to be more attentive to details. Their records evolve around describing what they see, touch, hear, smell, and occasionally taste. ("Taking samples" by sketches, and possibly photographs, recorded by the students rather than by taking part of the plant minimizes impact on that area, and prevents picking what may be a rare species.) Students must practice attention to detail by taking accurate notes. From the accumulation of data, students have their own database of information to use for reports and creative writing. Using the journal over a period of several years reveals growth in ability but also provides information for showing changes in knowledge.

Projects involving the cultural resources of a region fit right into the social studies programs taught in Texas public schools. Applying information learned in the textbooks to the region in which the student lives helps to make a real-life connection. Finding people from the community that can enlighten the students through their own experiences or from their knowledge of the past makes social studies personally meaningful. Experiences such as this project lead the student from the low level thinking skills of simple recall into higher levels of thinking as they apply their skills and knowledge to the unexpected.

## Tackling Issues

**Environmental issues** consist of conflicts that arise from how people view problems. (J. R. Gardella, *Environmental Education Curriculum Inventory*, School of Education, Northern Kentucky University, 1993)

The goal of environmental education is to develop a citizenry that is capable of making responsible decisions and taking action. Issue analysis and action projects give the learner the opportunity to go beyond just awareness and knowledge. Through such first-hand practice, the young citizen begins to feel that he or she can make a difference whether it's in one's personal life, home, community, state, nation, or world.

Learning more about your region means recognizing that problems may exist that affect the quality and quantity of resources. Issue analysis goes the additional step that looks at the impact not only on resources, but also social , economic, politic and cultural impacts. Part of effective citizenship is believing that humans have the ability to bring about change in a positive direction to solve or improve environmental problems.

Knowing and understanding the place where a person lives builds on a foundation of awareness. Through that awareness the person realizes why the region in which he or she lives holds special meaning. As pride and respect for the land and culture grows so does the desire to care for the environment. Why should a person care for something that has no personal meaning?

As knowledge and skills increase, so does the ability to identify problems, analyze positions on the issues involved, find ways to solve the problem, and make decisions as to possible action. By developing citizenship skills, youth will have the opportunity to develop responsible, well-informed decision-making.

An essential aspect of tackling environmental issues is allowing "all sides" to be heard. Don't interject a personal agenda or conclusion. Issues are by nature complex. Learning how to cope with differing information and differing opinion is an essential life skill.

### Taking Action

Participants who choose to work on issue analysis and want to involve their group in an action project have special assistance through the booklet Taking Action: An Educator's Guide to Involving Students in Environmental Action Projects by Project WILD and the World Wildlife Fund. The guide includes descriptions of over 30 successful projects from around the United States.

Helpful guidelines assist with choosing action projects, steps that facilitate the process, clues to resolving conflicts, help with interviewing tips and brainstorming, models for mapping out the project, and samples to help with assessment and evaluation.

Project WILD makes this booklet available for $7.00. You may contact the Project WILD state program leader at TP&W headquarters or their national office at Project WILD, 5430 Grosvenor Lane, Bethesda, MD 20814 (301) 493-5447.

## Choosing a Project

We hope that at this point you're excited about the many options before you. You may chose nature studies, cultural investigations or expressions, or probing issues.

Consider the interests of your group. If the group becomes part of the decision making process, they remain more eager and active learners. Their age and experiences will help determine the length and depth of the project.

As the project leader, you don't have to be an expert scientist or historian. Organizational skills are very important, however. Consider several questions as you guide your students toward selecting a project focus. Can the group do the planning and preparation? Will they be able to follow through? Develop not only project goals but direct the group, if they are old enough, through timelines as well. Help them take on a project marked for as much independence and success as possible – and define that measure of success at the onset of the project.

Consider how much preparation time this will take. How much time do you have available? Do you have local resources to call on?

Plan on ample time for research and producing your results, anywhere from one to six weeks. Although the project has the potential for extension beyond that time frame, you should complete the work within twelve months. The group may choose to become involved again and do other projects in the future. Such participation can lead to higher levels of awareness, knowledge, thinking skills, value formation, and empowerment as citizens.

Remember to focus on the region in which you live. What can you learn about the natural and/or cultural resources? One perspective might be to think about yourself becoming a mini-expert gaining information about some particular aspect of the natural resources such as the wildlife, plant life, and/or geology. Another might be to look at yourself as being a traveler in time. What would you see going on around you where you are standing right now? What groups of people lived there?

Natural and/or cultural history might interest you. A person or event specific to your region could interest your group. What artifacts remain or what types of architecture from different periods of time exist? Another point to consider is the availability of community resources. Guidance and assistance could come from that person or group. Any of these ideas could lead you to a possible project.

Another option is "service learning." You choose a topic or location to learn about, with the help of local managers. In exchange for their assistance and expertise, your group offers a service project chosen by the land or water manager. A wonderful partnership and citizenship action result. This model of learning is gaining in popularity in other states.

Issue-analysis requires the greatest discipline and time commitment, but reaps unparalleled citizenship experience. Workshops and materials for this are available.

Remember that TP&W, if needed, will be helping you with their resources once you begin your work. Our support may come in terms of materials, experts to answer those questions to which you have not been able to find the answer, or interpretation during a field trip to a natural or historical site.

## The WEB Connection

Thousands visit our world wide web site every day from every corner of the globe. We look forward to sharing your group's findings on our site. What better way to represent the diversity of Texas than through the eyes of our youth? The appendix includes a template and style guide for your web page(s).

You may submit data, reports, creative writing, drawings, or photos. At the time of this writing, video clips or sounds of more than a few second duration are difficult to transmit on Internet. Please read the web page style guide carefully and feel free to contact the TP&W project coordinator with any of your questions.

If submitting drawings, pictures or posters, please have them scanned at a low resolution and saved on a floppy disk. Again, details on picture file formats and size limitations are listed in the style guide.

Several things to keep in mind when designing web pages: The Internet represents fresh, interesting, conversational information. Keep in mind that if what you're considering isn't interesting or compelling to the person next to you, it won't be of much interest to web "surfers." Make your pages come alive with insightful or telling observations, unique perspectives or presentations, and be accurate. You will be hosted on a state agency site, and with that privilege comes responsibility. We will hold you to that responsibility. We value our site and truly want your pages to be quality contributions to the information about our state.

## Submitting the Project Description

Look at the back of the notebook for the form to submit for acceptance of your project. Describe as clearly and concisely as possible the objectives of your project.

TP&W will review your project with you before you begin to ensure that the topic will be appropriate for the web site. Although we encourage creativity, we will check for responsible language, accuracy, and if issue-based, evidence of scientific inquiry. You'll want your project to be next to other projects of quality, and we must maintain the integrity of our web site. Having said this, let's clarify that pictures drawn by Kindergarteners will still be welcome, as long as they actually observed what they drew! And we won't be editing their drawings for color or feather pattern!!

Mail your project description to the following address:

Exploring Texas
Texas Parks and Wildlife
4200 Smith School Road
Austin, Texas 78744

# Let the Expedition Begin

Each teacher or youth group leader comes to the project with his/her own set of background experiences and skills. The following section compliments those differences and provides a possible way of getting the job done. Feel free to go on with your own game plan if you so desire.

As you set out to explore your region of Texas, you and your group have already plotted a course in your project description. Now you need to plan how to reach your destination. What routes you take and the tools/supplies that you have available greatly affect the outcome. Plan and prepare for success.

1. Record what you already know.
2. Then record what you want to know.
3. Think together who might have or where you would obtain the information you want to know, when you need the information, and who will be responsible for contacting or obtaining the resource.

Begin by looking at the materials that you and the group have around you.

Check out schools and local libraries for reference books, histories, biographies, field guides, or nonfiction books that can get you started.

Have the children go through the resource directory (and your local phone!) book with you. Think about the people in your area that might serve as a resource. Tell parents and friends about your project and request their help in tracking down materials or people. Learning how to scope out resources is a skill worthy of development!

Have your questions well prepared and narrowed in scope. (Asking someone to "Tell us everything" is an impossible request, and met with limited success.)

Vary your sources. You'll find interesting perspectives by comparing publications, films, interviews, and trips and by using different resource organizations.

Make predictions about where and how those answers might unfold. Might they come from books, people, or exploration outdoors? Be alert to possible misconceptions. As the study develops, compare predictions with actual findings.

Keep records individually or by the group. Learning to keep a journal, whether a nature journal or a historical journal, of your experiences is beneficial and provides you with steady references when writing your material for the web page(s).

# Working with TP&W

As you search for resources in your area, you may want to also use brochures, videos, and maps available through TP&W and other state agencies. In some cases, TP&W staff may be available to answer those most difficult questions, or offer a facility tour. TP&W's field offices are busy places, including law enforcement offices, fish and wildlife research and management areas, fish hatcheries, park rangers and urban biologists.

We've listed below resources available through TP&W. Other state agencies have jurisdiction over similar resources, but with different roles. To help understand the distinction of roles, we've listed some of them here. A more complete listing is in the TEAN guide in the appendices.

Contact the TP&W Exploring Texas coordinator for assistance in ordering materials or locating local TP&W resources.

### Publications

The "Resources" section contains a list of publications available from TP&W. You are welcome to order single copies of free publications. In addition, the Publications Section lists a variety of books and posters for sale. You'll find an order form at the end of the resources section.

### Videos

TP&W offers entertaining and educational videos through the weekly PBS series, Texas Parks and Wildlife. The appendix contains descriptions of all segments of each program for the past three years. In addition to copies of weekly shows, you may also purchase videos compilations such as Destinations, The Best of TP&W; Birding Texas, Outstanding Texans, and others. Complete listings are in the appendix.

### Facilities Owned by TP&W

The public land managed by the department includes parks, natural areas, historic sites, wildlife management areas, fish hatcheries, research/demonstration areas, and field offices. Field trips can often be arranged. Preparation beforehand makes the trip much more than just an outing to the park. Preplan with staff. Interviewing and note taking skills take on new meaning when the children are on a fact-finding mission.

If traveling to the facility poses a problem, then letter writing suffices as the next best method. Letters should narrow the field of inquiry to request information more specific to your project rather than asking the interpreters to send you anything that they have. Having the youth share what they have already found tells the reader that the group has been working. Some areas offer outreach programs and make visits to schools or meetings.

Part of the planning that goes into the development of a state park involves thoroughly researching the biological, geological, and historical facts surrounding the area. Compiled in the Master Plan, the staff uses the material for the development of the park and to produce booklets, pamphlets, displays and material for guided tours. For youth involved in more advanced research, the park interpreters can copy pages from the Master Plan. The bibliographical references in the Master Plan can also be helpful.

The Historical Parks throughout the state fit into twelve chronological periods. Knowing that designation provides a key to the information from that site. Table 1 details the chronological designation of historical parks.

Many of Texas' state parks owe their development to the diligent and lasting work of the Civilian Conservation Corps (CCC) during the 1930s. Other parks represent facets of history and feature living history or educational exhibits. Parks rich with significant historic components are listed in Table 2.

## Natural Resources:

### Texas Environmental Awareness Network (TEAN) Guide

This association of state agencies and environmental education organizations dedicates its activities to cooperative promotion of environmental public awareness. Their excellent guide, included in the appendix, provides the names of all of the state agencies involved in TEAN, descriptions of each agency, phone numbers, annual events, and order blanks for educational materials. Projects that involve the natural resources and issue analysis should find this guide beneficial.

### Texas A&M Agricultural Extension

Extension agents are an absolute treasure of resources. Agriculture and home economic agents serve each county with information based on the research of Texas A&M, as well as information and guidance specific to the county. Additionally, extension employs experts on everything from bugs and soils to local plants and wildlife.

### Texas Parks & Wildlife

In addition to state parks and wildlife management areas, TP&W employs conservation scientists who manage the state's natural resources. Fish and wildlife belong not to a property owner, but to the people of Texas. To responsibly manage fish, wildlife, and their supporting habitat, TP&W biologists research, track and manage for the health of habitats, species diversity and sustainability. TP&W biologists also offer guidance to private landowners, developers and urban planners.

### Texas Natural Resource Conservation Commission

TNRCC may be best understood as the state version of EPA. TNRCC has regulatory oversight for protecting air, water, and land resources in Texas. TNRCC has wonderful educational efforts and are resources for citizen action projects such as recycling or cleanups, as well as information on pollution. Details and contact numbers are in the TEAN guide in the appendices.

## Archeology & Cultural Resources:

### Texas Historical Commission (THC)

Texas Historical Commission archeologists investigate, gather, and preserve the remnants from the past, and offer assistance to private landowners.

Office of the State Archeologist
Texas Historical Commission
P.O. Box 12276
Austin, TX 78711-2276

Volunteer Speakers & Mentors

Texas Archeological Stewardship Network
Office of the State Archeologist
Texas Historical Commission
PO Box 12276
Austin, TX 78711-2276 (512) 463-8884

## Texas Parks & Wildlife Cultural Resources Program

During the past quarter century, the Public Lands Division of Texas Parks and Wildlife Department has acquired, restored, preserved and operated historic properties, through a legislative mandate, to assume stewardship of important elements of Texas' heritage. TP&W holds a continuing commitment to this responsibility through the TP&W Cultural Resources branch. Archeologists, historians, and interpreters offer insights on state parks and historic sites. Materials and information available.

Archeology and Cultural Information on Public Lands:
Cultural Resources Program
Texas Parks & Wildlife
4200 Smith School Road
Austin, TX 78744

## Maps:

### Texas General Land Office

Find original county maps that date back to the early 1800's, and acquisition maps going as far back as the Spanish Land Grants. Using maps provides insight into the patterns of settlement and development.

Archives and Records Division
Texas General Land Office
Stephen F. Austin Building
1700 N. Congress Avenue
Austin, TX 78701-1495

### Bureau of Economic Geology

Explore natural history of ecoregions through geological maps from the Bureau of Economic Geology. Forty six different maps are available from the Geologic Atlas of Texas. Each packet contains a booklet describing geological deposits and formations. The Geoscience Publications of Special Interest to Teachers and Students of Earth and Environmental Sciences In Texas gives prices and ordering information.

The Geological Highway Map of Texas provides a colorful overall view of the geologic formations and gives a chart of time and rock units for five sections of the state, a tectonic map, physiographic map, a series of maps showing the restless crust of Texas, two cross sections indicating the elevation of the crust and the known depth of formations along with much more information.

The bureau offers assistance to you through the Public Information Geologist. This staff member provides individualized help with those questions that surface when you have exhausted your local resources. Your inquiries access information not ordinarily available to the public.

Bureau of Economic Geology
The University of Texas at Austin
University Station, Box X
Austin, Texas 78713-8924

## Issue Analysis

### University of Houston

Issue analysis is a comprehensive and structured process for tackling complex problems. The process examines all facets of decision making, including the impacts on the economy, culture, natural resources, and political climate. The goal of issue analysis is using objective, scientific inquiry and critical thinking skills to develop citizenship skills. Workshops and curriculum guides are available. For more information, contact John Ramsey at the University of Houston.

John Ramsey
University of Houston
Houston, Texas 77204-5872

### Project WILD and Aquatic WILD

Learn hands-on activities illustrating environmental concepts through the Project WILD workshop and activity book. Contact TP&W to participate in a Project WILD or Aquatic WILD workshop.

Action Guide: Being a leader for an action project requires preparation, organization, and strategies for effectiveness. This guide offers great suggestions. Contact the national Project WILD office to order.

Project WILD
5439 Grosvenor Lane
Bethesda, Maryland 20814

## Web Resources

You'll find a wealth of resources on the Internet on literally millions of subjects. Some of our favorite "search engines" include AltaVista and Yahoo. Favorite educational sites include TENET for Texas teachers and ERIC, an environmental education clearinghouse.

## Submitting Your WEB Pages

Follow the TP&W web page template and guidelines. Please submit your web pages on either an IBM-compatible or Macintosh 3.5 inch floppy disk. Using a padded envelop, send your disk to Exploring Texas, TP&W, 4200 Smith School Rd, Austin, Texas, 78744.

## Field Test Evaluation

Your evaluation of this project is essential to its success. You'll be judging the quality, usefulness and effectiveness of the workshop, this manual, the educational value of the project for the participants and the project as a tool in your mission as teacher or youth group leader.

Please return your evaluations when you send us your web page disk.

# Table 1: Designated Historical Parks

| Park | Cultural Period | Locality | Acquisition |
|---|---|---|---|
| Acton | 6 | Acton | 1911 |
| Admiral Nimitz Museum | 12 | Fredericksburg | 1984 |
| Battleship Texas | 12 | La Porte | 1983 |
| Caddoan Mounds | 3 | Alto | 1975 |
| Casa Navarro | 6 | San Antonio | 1975 |
| Confederate Reunion Grounds | 9 | Mexia | 1984 |
| Eisenhower Birthplace | 12 | Denison | 1959 |
| Fannin Battleground | 6 | Goliad | 1965 |
| Fanthrop Inn | 8 | Anderson | 1977 |
| Fort Griffin | 10 | Albany | 1935 |
| Fort Lancaster | 8 | Sheffield | 1967 |
| Fort Leaton | 8 | Presido | 1967 |
| Fort McKavett | 10 | Fort McKavett | 1967 |
| Fort Richardson | 10 | Jacksboro | 1968 |
| Fulton Mansion | 10 | Rockport | 1976 |
| Goliad | 4 | Goliad | 1932 |
| Governor Hogg Shrine | 11 | Quitman | 1946 |
| Hueco Tanks | 3 | El Paso | 1969 |
| Jim Hogg | 8 | Rusk | 1941 |
| Kreische Brewery | 10 | LaGrange | 1977 |
| Landmark Inn | 8 | Castroville | 1974 |
| Lipantitlan | 6 | San Patricio | 1937 |
| Lubbock Lake Landmark | 1 | Lubbock | 1988 |
| Lyndon B. Johnson | 12 | Stonewall | 1966 |
| Magoffin Home | 11 | El Paso | 1976 |
| Mission Rosario | 4 | Goliad | 1972 |
| Monument Hill | 7 | LaGrange | 1949 |
| Old Fort Parker | 5 | Groesbeck | 1936 |
| Port Isabel Lighthouse | 8 | Port Isabel | 1950 |
| Sabine Pass Battleground | 9 | Sabine Pass | 1972 |
| Sam Bell Maxey House | 10 | Paris | 1976 |
| San Jacinto Battleground | 6 | La Porte | 1965 |
| San José Mission | 4 | San Antonio | 1941 |
| Sebastopol House | 8 | Seguin | 1976 |
| Seminole Canyon | 2 | Comstock | 1973 |
| Starr Family Home | 11 | Marshall | 1976 |
| Texas State Railroad | 12 | Rusk | 1971 |
| Varner-Hogg Plantation | 12 | West Columbia | 1956 |
| Washington-on-the-Brazos | 7 | Washington | 1916 |
| Zaragosa Birthplace | 6 | Goliad | 1961 |

The designated Historical Parks fulfill a framework of Texas History derived in 1970. Each park has been assigned to one of twelve chronological periods: 1) Paleo-Indian, 2) Archaic, 3) [illegible]-American, 4) Early Exploration and Colonization, 5) Ealry Anglo-American and European Colonization, 6) Mexican Texas and the Revolution, 7) Republic of Texas, 8) Early Statehood, 9) Confederate Texas, 10) Reconstruction, 11) Victorian, and 12) Twentieth Century Texas.

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# Table 2: Parks with Significant Historical Components

| Park | Significant Component | Location | Acquisition |
|---|---|---|---|
| Abilene | CCC | Tuscola | 1933 |
| Balmorhea | CCC | Balmorhea | 1934 |
| Bastrop | CCC | Bastrop | 1933 |
| Big Bend Ranch | Prehistory, Mining, Ranches | Presido | 1988 |
| Big Spring | CCC | Big Spring | 1934 |
| Blanco | CCC | Blanco | 1933 |
| Bonham | CCC | Bonham | 1933 |
| Buescher | CCC | Smithville | 1933 |
| Caddo Lake | CCC | Karnack | 1933 |
| Caprock Canyons | Prehistory | Quitaque | 1975 |
| Cedar Hill | Penn Farm | Cedar Hill | 1981 |
| Cleburne | CCC | Cleburne | 1935 |
| Daingerfield | CCC | Daingerfield | 1935 |
| Davis Mountains | CCC | Fort Davis | 1934 |
| Devils River | Prehistory | Del Rio | 1988 |
| Fort Boggy | Homesteads | Leona | 1986 |
| Fort Parker | CCC, Townsite | Mexia | 1935 |
| Franklin Mountains | Prehistory, Mining | El Paso | 1981 |
| Garner | CCC | Concan | 1934 |
| Goose Island | CCC | Rockport | 1931 |
| Government Canyon | Homestead | Helotes | 1993 |
| Guadalupe River | Homestead | Spring Branch | 1974 |
| Huntsville | CCC | Huntsville | 1934 |
| Indian Lodge | CCC | Fort Davis | 1935 |
| Inks Lake | CCC | Burnet | 1940 |
| Kerrville-Schreiner | CCC | Kerrville | 1934 |
| Lake Brownwood | CCC | Brownwood | 1934 |
| Lake Corpus Christi | CCC | Mathis | 1933 |
| Lake Mineral Wells | WPA | Mineral Wells | 1976 |
| Lake Ray Roberts | Jones Farm | Pilot Point | 1990 |
| Lockhart | CCC | Lockhart | 1934 |
| Longhorn Cavern | CCC | Burnet | 1932 |
| Matagorda Island | Lighthouse, Civil War | Port O' Conner | 1982 |
| McKinney Falls | Prehistory, Homestead | Austin | 1970 |
| Meridian | CCC | Meridian | 1933 |
| Mission Tejas | CCC, Rice Log Home | Weches | 1935 |
| Mother Neff | CCC, Prehistory | Moody | 1923 |
| Palmetto | CCC | Gonzales | 1934 |
| Palo Duro Canyon | CCC | Canyon | 1933 |
| Possum Kingdom | CCC | Caddo | 1939 |
| South Llano River | Buck Ranch | Junction | 1977 |
| Stephen F. Austin | Townsite | San Felipe | 1940 |
| Tyler | CCC | Tyler | 1934 |

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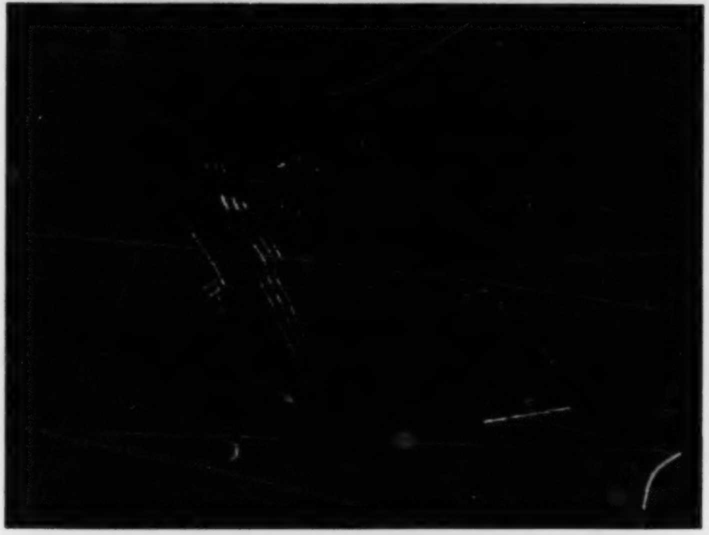
**Alan J. Cherepon**
**Composite Science**
**Westwood High School, Round Rock ISD**



**Texas Parks & WIldlife, Austin**
**Steve Hall, Mentor**
**Scotty Oliver, Mentor**

# TTIP
# CURRICULUM IMPLEMENTATION PLAN
## Abstract

**NAME:**Alan J. Cherepon

**INTERNSHIP:**Texas Parks & Wildlife Department-Austin

**SCHOOL:**Westwood High School, Round Rock ISD

**PRIMARY SUBJECTS:**Physical Science, Principles of Technology, Astronomy, Geology

**ACTIVITIES:**Operation and tweeking of DART Target System(mobile, laser disc operated, computerized shooting range for hunter education), Creation and tweeking of database for hunting accident reports(using existing database in Access).

**OBJECTIVES:**Application of various aspects of the DART system into physics; Pulley and cam system on compound bows, mechanical advantage, estimation of force versus distance for arrow projectile, force transfer from bow (string) to arrow, concepts behind infrared lasers and sensors and application to security and other systems, optics of projector, systems analysis and construction in science application, instruction manual for technical communication, and for long term/continued development-develop a Physics of Hunting manual for use and distribution to both schools and the Texas Parks & Wildlife Department. Database applications in classroom-comparison between spreadsheets and databases and applications with scientific data input, manipulation, and interpretation.

**SUMMARY:**High Tech, Hunting and the use of firearms and archery equipment are subjects that interest many students. By applying the physical laws behind the operation of these components of the DART Target System, students and hunters can better learn the proper use of the equipment required for these activities. The integration of the basic physics and high-tech applications to firearms and hunter education should help students realize the practical applications of physics to all aspects of society, as well as providing an enjoyable way to introduce them to the world of interactive systems spawning from the high-tech industry. Development of a unit on these aspects of hunting will teach them physics application in an interesting and enjoyable manner, provide an application of system integration and teamwork concepts stressed in lab activities, and the other elements of the instructional development model. Numerous life-lessons, including safe firearms handling and hunting procedures, can be incorporated as potential life-savering instruction. Use of the operations manual with the actual system can also serve as instruction for technical communications. Continued development of the unit can be enhanced by communication and input on the Internet by teachers and those involved in hunting and firearms and serve the hunter education programs around the country.

**RESOURCES:**Texas Parks & Wildlife Department, Hunter Education Section-Steve Hall/Scotty Oliver, 4200 Smith School Rd., Austin, TX 78744-3292;(512)389-4000.Internet access-steve.hall@tpwd.state.tx.us or scotty.oliver@tpwd.state.tx.us

DART International, Don Ward, 1390 S. Potomac, Suite 100, Aurora, CO 80012;1-800-745-7501

Browning, Research & Development, Archery, Mike Sealover, Rt. 1, Morgan, Utah 84050;1-800-333-5125, ext. 46

# CURRICULUM IMPLEMENTATION PLAN

Alan J. Cherepon-Westwood HS, Round Rock ISD
Texas Parks & Wildlife Department-Austin, Texas

## DESCRIPTION/OBJECTIVES

This Curriculum Implementation Plan (CIP), developed as part of the requirements for the Texas Teacher Internship Program (TTIP) at Texas A&M University, details the objectives, strategies, materials, and references for the begining of a Physics of Hunting unit plan, based on experience and information gained at the Texas Parks & Wildlife Department, Hunter Education Section, Austin, Texas(Ref.1), during the summer of 1996. Primary work tasks included the operation and tweeking of a new DART Target System(See Ref. 2), a mobile, interactive, computer operated shooting range, which focused on educating hunters to greater awareness of the TPWD's Hunter Education programs, including proper firearms handling and hunting technique. Sufficient application of physics, as per telephone communication with Browning (Ref. 3), and high-tech were incorporated into the overall system to integrate these applications into the beginings of this Physics of Hunting unit for use in both the classroom and possibly State Hunter Education programs. The application of high-tech systems to recreation provides a practical application of teamwork concepts utilized in science labs, demonstrates the need for creativity and problem-solving skills in science. This instructional unit is not a completed, "end-all" document, but is hopefully the foundation for a growing set of lessons that will help make physics more real, interesting and palletablethrough integration with sport and recreational activities. Added bonuses could include safe hunting and firearms handling, which could save lives, as well as a greater appreciation for this sport and the monies the hunting program provides to preserving our wildlife resources in Texas and the USA. Addionally, developing/customizing hunter accident database provided insights into many teacher/classroom applications.

Specific expected objectives of this curriculum include:

- Clearer understanding/calculation of mechanical advantage(using compound bows-See Ref. 5-6)
- Application of force transferal from bow to arrow and determination of trajectory and bow's practical shooting distance(See Ref. 5-9)
- Develop better problem-solving skills by back-calculating various values for archery
- Use of simple and compound machines in such matters as stringing a recurved bow(See Ref. 10)
- Principles of infrared lasers and sensors in an interactive system and elsewhere
- Optical principles of projector and transfer of images from laser disc to projector to screen
- Teamwork, problem-solving/critical thinking skills development with component integration and system development
- Application of known interactive systems(computer games), newly acquired knowledge of such systems(DART) and projecting for future applications(holodeck in Star Trek-The Next Generation) and more immediate educational uses(flight-simulators/driver's ed, etc.)

- Database/spreadsheet comparison and applications(Ref.1 and 11) to science and non-science
- Teacher use of database for tracking/evaluating teaching methods and students, tracking continuing ed/professional development and documentation/record keeping/organization (See Ref. 1)

## STRATEGIES

One of the most effective teaching methods for teaching difficult concepts in science and math is to integrate the lesson with something the students are familiar with and enjoy, or at the very least, are interested in. The interactive, high-tech applications to computer games and virtual reality has quickly captured the minds and dollars of most students. The Dart Target System has taken the existing technology as components in the laser disc, computer, large-screen projector, sensors, infrared lasers, and various firearms and has integrated them into a sport and training system. Already police and other firearm/archery training facilities are utilizing these systems much the same way flight simulators are used tomore efficiently train pilots, especially for the novice. Computer software includes such products as 3-D architectural programs for designing, building and decorating a house or business. Television and movies have even projected educational applications of this technology in such shows as Star Trek-The Next Generation, or one of the Star Trek movies. The characters train on a holodeck, where holographic, 3-D virtual reality has taken the next step of tricking your senses into seeing and experiencing things that are only images. Between these examples and the plethora of Nintendo- or Sega-Genesis-type interactive computer games, students both know of and enjoy such applications of technology.

The DART system's many components apply various principles of physics that can be incorporated in Physical Science, Physics, Principles of Technology, and Astronomy courses. Strategies for teaching each of the objectives bulleted in the above section are detailed below.

### • FORCE TRANSFER, MECHANICAL ADVANTAGE, EFFICIENCY, AND TRAJECTORY

The concept of transfer of force is simple enough, except when considering the various loses that occur in the process. Using a compound bow and arrow, a Newton Scale, double chronographs, and some simple formulas and curves, numerous calculations can be made on the physics of the bow and arrow. More adventurous calculations involving force vectors could also be applied to test the effect of placing the nock of the arrow(rear grove where the string fits into arrow) at various offset distances along the serving (middle portion) of the bowstring(See Ref. 4 for diagram and nomenclature of compound bow and arrow). The bow manufacturer provides statistics on the bow, such as the draw weight (ex. 60lb bow), percent let off (reduction from draw weight at peak) and force draw and/or velocity to weight curves. The actual values the manufacturer or another source (Bowhunting World magazine, Ref. 5) provides can be tested and compared to determine how these values were derived, a good means of developing problem-solving skills and teamwork in lab. (Provided values will not be the same as those students will get, as the testing labs that derive these values use mechanical devices(robots)to draw and shoot arrows and trigger the chronographs for consistent results). Comparisons can also be made between different bows to determine which is better, and will also demonstrate if students are truly grasping the concepts involved. Presentations and/or writeups can be required to stress oral and written communication skills.

The beauty of the compound bow, and the general physical laws applied to it, can best be explained by comparison to firearms (Ref. 6). The rifle has a longer barrel than a handgun, thus applied force is over a greater distance(barrel length). The same principle is used in the compound bow as compared to other bows. An eccentric pulley(cam) applies greater force over a greater distance, as the arrow is already moving when it reaches peak pull weight at mid-draw distance. Thus, more foot-pounds of energy are applied over a longer distance.

The pulley system is like a miniature block and tackle, having 3 supporting strands (a mechanical advantage of 3). The eccentric pulley, or cam, is either an elliptical shape or wheel mounted off axis. This provides varying mechanical advantage as the string is drawn, comparable to suddenly lengthening the bow limbs on a recurved bow, resulting in a longer lever arm. The mechanical advantage can be seen on Force-draw curves(See Fig. in Ref.5), where the force required to draw the string back beyond peak draw decreases. Two of the cables are arranged as "feedback" in which they are both pulling on the limbs at the same time, with the same force, making the compound bow much more stable.

The cams transfer the mechanical advantage to the archer; when the cam turns over and locks into place at peak draw, less force is exerted by the archer as the force is now held by the cam. This relaxation in tension is typically 5-20% and serves two purposes; it allows the archer to hold at peak draw weight with less effort, thus reqiuring less energy and enabling one to hold at peak draw longer and steadier while waiting and/or aiming for an optimum shotting situation.

Unlike firearms, in which inertia is applied to the bullet alone, inertia in a bow system is not only applied to the arrow, but to each bow limb and the string. Each limb of the bow weighs at least 2 arrows in weight, so combining the weight of each limb and the arrow is like moving 5 arrows of weight. This is why reducing arrow weight only moderately increases arrow speed, as you only reduce no more than 1/5th of the total load.

The bow and arrow, even with continued improvements, will have certain physical and practical limitations. Stored potential energy is dependent upon the body strength and size of the archer's "reach" or arm and bow draw length. Also, since no system can have 100% efficiency(the best for bows are near 85%, due to frictional and vibrational losses),and even if you could achieve 100% efficiency, your shot would not be very accurate. Additionally, the trajectory for arrows is at a considerably greater slope than a bullet's, due to the velocity being an order of magnitude less, as well as the drawn-out shape(See Ref.5&6).

## • CALCULATIONS

Numerous curves and given data can be used to varying degrees of difficulty in determining the physical properties of the bow and arrow. The most important are the Force-Draw curve and the Arrow Initial Velocity-Weight curve(See Ref.5). Students can create their own and compare them to standard curves to check results. Equipment includes at least 2 different bows, a Newton Scale capable of reading up to 70 foot-pounds of force, and a setup for keeping the bow at the same place while drawing back the string and measuring draw in inches and force in foot-pounds at set intervals. Calculation of the area under the curve will give you the Potential Energy or Stored Energy of the bow.

The Velocity-Weight curve can be constructed by setting up two chronographs(digital timing gates) in line; one to begin the time and the other to stop the clock as the arrow sails past a known distance interval. With distance and time data, the velocity can be calculated. The weight of the arrow can be either converted from the known weight in grains to pounds(7000 grains = 1 pound) or placed on a balance scale and converted from metric to English units(the many conversions involved in this work will be good exercise for the students, teaching them to be careful, organized, and improving their math skills). From this data, the Kinetic Energy can be calculated($KE=1/2mv^2$), and a conversion factor of 7000 * 31.26 for grains to pounds and affect of gravity on arrow. The amount of output for amount of input force, or Dynamic Efficiency, can then be calculated by setting up a ratio of KE to PE (or KE:PE )which includes the conversion factors from the KE calculation and will be a %. 437,640

The Velocity-Weight curves can be used to velocity for any arrow, and can be checked by shooting various arrows and recrding velocities to check accuracy of the student's calculations. Arrow trajectories can also be determined once the initial velocity and weight are known. Estimates can be made, such as if an animal were so far away, and you had a bow and arrow that provided a velocity of 280ft/sec., is it even sensible to take the shot or try to get closer, and how close do you need to get to get a good shot, etc. The various charts and methods for calculating trajectory are provided in Ref. 7 & 8, interchanging various values to check to see if they are grasping a working knowledge of the physics and math involved.

One additional exercise could include a comparison writeup report(similar to a consumer report) and even a presentation by the team to improve communication skills. This could involve spreadsheet tabulation of data and computer-generated curves to enhance the reports and help with calculations and organization. Career opportunities could be discussed at this point, demonstrating the various positions for these skills.

- **LASER, OPTICS, AND SYSTEM DEVELOPMENT**

The Dart system has two applications of lasers; one is in the laser disc player that has the various scenarios of animals and targets to shoot at, and the other is an infrared laser mounted in the firearm barrel that shoots an invisible beam at the screen. The sensor, mounted below the projector, detects when the laser or arrows impact the screen. Together, these components demonstrate one application for these segments of the electromagnetic spectrum and can be used as a demonstration of how laser security systems operate, as well as a lead-in to the various types of lasers being used today. The projector is a good example for optics study and a demonstration of energy signal transfer from the laser disc and computer to the projector and screen, culminating in the integration of various components into specific systems. The point can be stressed for being well-read and current on technology developments, as well as the need for creativity and teamwork in system development and applications to previously untapped areas, such as hunting. These lessons and examples will hopefully expand student's ways of thinking (to overuse an overused word-paradigm shift).

Numerous applications of interactive technology can be found around us, including flight simulators, educational and entertainment software, and the virtual reality systems that are in their infancy stages. Another exercise would be to show examples of these, explaining what interactive means, and give examples of projected uses in the future(such as the "holodeck" in Star Trek-The Next Generation, where it is used for training for dangerous situations without having to realy be put in that situation. This is similar to the DART system, in that hunters can train where and when to take a shot on animals that they may not see in their part of the world. students should be allowed time to name other examples of this technology and to exercise their creativity in coming up with their own ideas on where this might be useful.

- **DATABASE**

Databases and spreadsheets are extremely useful tools, especially in science. The similarities and differences should be presented, or as a problem solving skill(time permitting), have students work with both and write a short summary on this. The most useful features include the organization, manipulation, and interpretation of data. Graphical interpretatations (Ref. 11) usually make trends and interesting or bad data points stand out, and can be utilized for tracking certain data. Their use for physics labs are invaluable in not only teaching students the best ways to deal with large amounts of data, but also how to set up mathmatical formulas and conversions for computer calculation, and can also serve as a lead-in for how we use databases and graphs in such jobs as auto parts stores, auto mechanic's and doctor's usage for diagnostic work, construction estimates such as density of materials curves for loading stresses and materials determination, sales and distribution reports and forcasting, financial planning, and even in sports, such as football scouting reports. Once students become aware of the many applications in everyday life and work, they become more motivated to learn these seemingly difficult aspects of technology.

Specific uses of database during the internship involved changing an existing database from another state to conform to the needs of Texas Parks & Wildlife Department for hunting accidents(Ref. 1). This involved basic computer skills, problem solving skills, and a finished product for use in the annual report. The most readily apparent usefulness was in demographic aspects, such as what areas had the most accidents to see if there are special needs, especially in education, and if certain age groups or other factors were involved in the accidents. Teachers could utilize the same principles for tracking students and teaching methods from year to year. The database helps to see trends and specific needs and changes(good and bad). Continuing education and professional development, as well as documentation and organization of a teacher's vital factors for our profession becomes easier once you get past the initial shock and effort involved in setting up or tweeking existing databases for your specific needs. And, after all, shouldn't we set the example for our students not to be technophobes, but instead, find new ways to incorporate time-saving technology into the schools? If we do not, other nations may surpass us, with the potential for a Third World status for the USA if we fail to motivate students in high tech and the sciences.

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# 1994
# TEXAS HUNTING ACCIDENTS ANALYSIS

Artwork Izaak Walton League of America

Federal Aid Project
W-104-S

WILDLIFE RESTORATION

For more information about hunting accidents
or the hunter education program in Texas, call (512)389-4999

# TEXAS: 1995
# A DIGEST OF INFORMATION COMPILED FROM HUNTING ACCIDENT REPORTS

This page needs a lot of "cleaning up"

### TYPE OF CASUALTY

| | |
|---|---|
| FATAL | 4 |
| NONFATAL | ~~37~~ 36 |

| | |
|---|---|
| SELF-INFLICTED | ~~20~~ 19 |
| TWO-PARTY | ~~21~~ 21 |

### FIREARM INVOLVED

| | |
|---|---|
| BOW | 0 |
| CROSSBOW | 0 |
| HANDGUN | 4 |
| MUZZLELOADER | 0 |
| OTHER* | 0 |
| RIFLE | 13 |
| SHOTGUN | 23 |

### DISTANCE FROM MUZZLE TO WOUND:

| | |
|---|---|
| "0-10" | 24 |
| "11-50" | 5 |
| "51-100" | 6 |
| "101+" | 1 |
| OTHER | 0 |
| UNKNOWN | ~~8~~ 4 |

### RESIDENCE OF SHOOTER:

| | |
|---|---|
| RESIDENT | 0 40? |
| NONRESIDENT | ~~35~~ |
| UNKNOWN | 0 |

### HUNTER EDUCATION (SHOOTER)

| | |
|---|---|
| Yes | 8 |
| No | 32 |

### SHOOTER PROSECUTED

| | |
|---|---|
| YES | 0 |
| NO | 0 |

### SELF-INFLICTED

| | |
|---|---|
| FATAL | |
| NONFATAL | |

### ANIMAL BEING HUNTED

| | |
|---|---|
| ANTELOPE | 0 |
| BEAR | 0 |
| BOBCAT | 0 |
| COTTONTAIL | 3 |
| COYOTE | 1 |
| CROW | 0 |
| DEER | 10 |
| DUCK/GEESE | 3 |
| DOVE/PIGEON | 13 |
| ELK | 0 |
| FOX | 0 |
| GROUSE | 0 |
| HARES | 0 |
| JAVLINA | 0 |
| MOOSE | 0 |
| NONGAME BIRD/MAMMAL | 0 |
| PHEASANT | 0 |
| QUAIL | 2 |
| RACCOON/OPOSSUM | 1 |
| SQUIRREL | 2 |
| TURKEY | 0 |
| WILD BOAR | 0 |
| OTHER UPLAND GAME BIRD | 0 |
| OTHER SMALL GAME | 0 |
| OTHER* | 0 |
| UNKNOWN | 1 |

### AGE OF SHOOTERS

| | |
|---|---|
| 1-09 | 0 |
| 10-19 | 9 |
| 20-29 | 5 |
| 30-39 | 9 |
| 40-49 | 4 |
| 50-59 | 5 |
| 60 AND OVER | 2 |
| UNKNOWN | 4 |

### AGE OF VICTIM

| | |
|---|---|
| 1-09 | 1 |
| 10-19 | 1 |
| 20-29 | 7 |
| 30-39 | 9 |
| 40-49 | 2 |
| 50-59 | 1 |
| 60 AND OVER | 0 |
| UNKNOWN | 0 |

### CAUSE OF CASUALTY

| | |
|---|---|
| VICTIM MOVED INTO LINE OF FIRE | 1 |
| VICTIM COVERED BY SHOOTER SWINGING ON GAME | 10 |
| VICTIM OUT OF SIGHT OF SHOOTER | 2 |
| VICTIM MISTAKEN FOR GAME | 1 |
| TRIGGER CAUGHT ON OBJECT | 1 |
| LOADING FIREARM | 3 |
| UNLOADING FIREARM | 0 |
| IMPROPER CROSSING OF OBSTACLE | 1 |
| DROPPED FIREARM | 1 |
| CARELESS HANDLING OF FIREARM | 7 |
| SHOOTER STUMBLED AND FELL | 2 |
| RUNNING/WALKING WITH LOADED FIREARM | 1 |
| REMOVING/PLACING LOADED FIREARM IN VEHICLE | 3 |
| USING FIREARM AS CLUB | 0 |
| DISCHARGE FIREARM IN/ON VEHICLE | 1 |
| FIREARM FELL FROM INSECURE REST | 3 |
| SHOOTING FROM/ACROSS ROADWAY | 1 |
| HORSEPLAY WHILE HUNTING | 0 |
| APPARENT USE OF INTOXICANTS/DRUGS | 1 |
| ARROW NOT MATCHED TO BOW | 0 |
| CARELESS HANDLING OF BOW OR ARROW | 0 |
| CARRYING NOCKED ARROW | 0 |
| DEFECTIVE BOW OR ARROW | 0 |
| STRINGING BOW | 0 |
| IMPROPER POWDER SUBSTITUTION | 0 |
| MIXED AMMO/INCORRECT AMMO | 0 |
| FAULTY EQUIPMENT | 0 |
| RICOCHET | 1 |
| OBSTRUCTION IN BARREL | 0 |
| OTHER* | 0 |
| UNKNOWN | 0 |
| FALL WHILE CLIMBING INTO POSITION | 0 |
| FAILURE TO USE SAETY BELT | 0 |

### VICTIM WEARING HUNTER ORANGE?:

| | |
|---|---|
| YES | 30 |
| NO | 0 |

BY TEXAS PARKS AND WILDLIFE DEPARTMENT
HUNTER EDUCATION PROGRAM

DART
TARGET SYSTEM®

# ARCHERY & COMBINATION SYSTEMS

The Dart Target System is a dynamic archery/firearms video target system designed specifically for the shooting sports retailer. The heart of the system is a technology commonly known as interactive video. The primary components include a computer, videodisc player, video projection system and a target face complete with an extremely accurate sensor. Our goal as a company was to develop a system that contributes measurably to the bottom line of our customers, enhances enjoyment and the skill level of the hunting sportsman, provides a communications link between the sportsman and manufacturers of shooting sports products and becomes a platform for the distribution of information critical to the future of shooting and hunting.

The end user of this system will experience situations that are as realistic as a simulator of this type can create. The sights and sounds are exciting, just as they are in the field. The decisions to shoot or not to shoot, picking your "spot" and the instant feedback on placement of the shot, are just a few of the elements built into the system.

## UNIQUE FEATURES

The Dart Target System is the only patented interactive video target system on the market and has many unique features incorporated into its design. These features include: over 800 video scenarios complete with critical audio; instant feedback to the shooter after every shot; an automated scoring system; league and competition format; a complete database function; a marketing function for advertising and promotion and a communications network linking all systems to the central computer at the offices of Dart International.

The software which controls the system was developed specifically for this product and is proprietary to Dart International. Additionally, the company has integrated off-the-shelf software to build valuable database and communications programs. The sophistication of the software and hardware that comprise this system are completely transparent to the end user. The computer technology used in the Dart Target System is very powerful and yet extremely easy to use. There is very little training needed to operate and maintain the system. All input screens are menu driven and are very simple to follow.

## COMPANY HISTORY

Dart International, Inc. was formed in April of 1990 and is a Colorado corporation. The company's mission is to identify and develop visionary products employing interactive multimedia technologies that contribute to the growth and prosperity of the shooting sports industry.

Dart installed its first video archery system in the fall of 1992 after extensive development and testing. In 1993, after its debut at the Bowhunting Trade Show and SHOT Show, Dart installed 80 target systems. As of January 1996, Dart Systems have been installed in more than 200 locations in 42 states, Canada, Mexico and China.

Dart International received a U.S. Patent on the Dart Target System in July of 1994. Specific information about U.S. Patent Number 5,328,190 is available upon request. The Dart System is the only patented interactive video target system for archery.

During 1994, Dart International formed an alliance of premier industry companies whose common goal is to promote the growth of archery and the shooting sports. These elite companies are committed to protecting and preserving the future of hunting and shooting. In conjunction with the Dart Mobile Systems, these companies will take their message to thousands of consumers attending shows and events throughout the United States.

The management team at Dart International is made up of a select group of professionals who are experienced in their roles and are dedicated to excellence. The strength of the entire Dart team lies in the depth of their experience and the complimentary skills each member contributes to the company.

Dart International has received the following recognition and awards:

Honored by *Outdoor Life* magazine as one of the fifteen "Outstanding People, Gear & Achievements" on the 1994 Honor Roll.

▲

Distinguished by *Bowhunting World* as one of the Top Twenty Hot New Products for 1993

▲

Featured on the ESPN program "Ultimate Outdoors" with Wayne Pearson in the Fall of 1995

▲

Recognized on The Nashville Network (TNN) Celebrity Outdoors Special, "Buck Madness", in November 1995

▲

Awarded the Special Achievement Award at the International CINDY Competition for innovative use of interactive technology.

DART
INTERNATIONAL, INC.
1-800-745-7501

## A TURN-KEY SYSTEM

This product is a turn-key system designed to drop into any existing retail or range facility. It is modular by design and all of the components are replaceable in the event of failure or malfunction. Dart's technical staff is available 24 hours a day on our 1-800 number to trouble-shoot any problem. Our standard practice is to swap out malfunctioning components using next day delivery services. The system has been designed to make this process simple and fast.

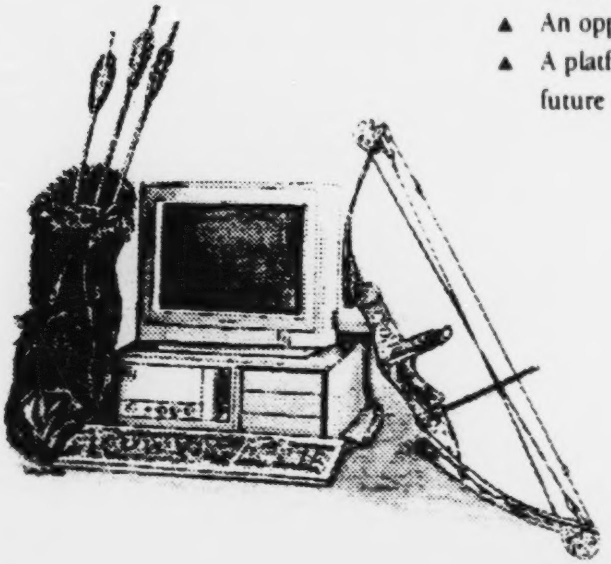
The Dart Target System is a revenue generating, marketing machine that has the capability to dramatically influence sales and cash flows at all installed locations.

The system has a built-in marketing and advertising function to accommodate advertising messages from leading industry manufacturers. This unique feature is intended to help support the sales of products and services in your store.

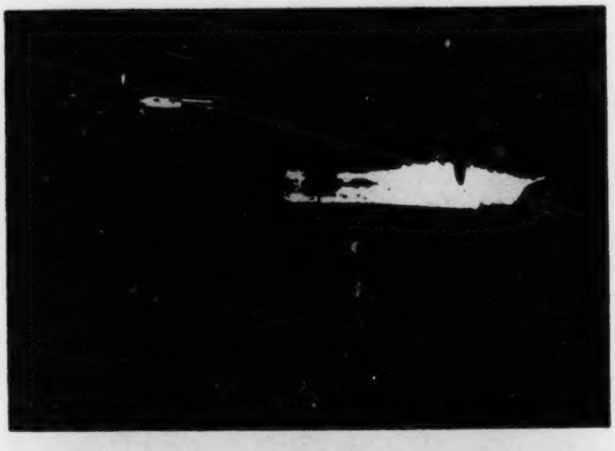
## BENEFITS

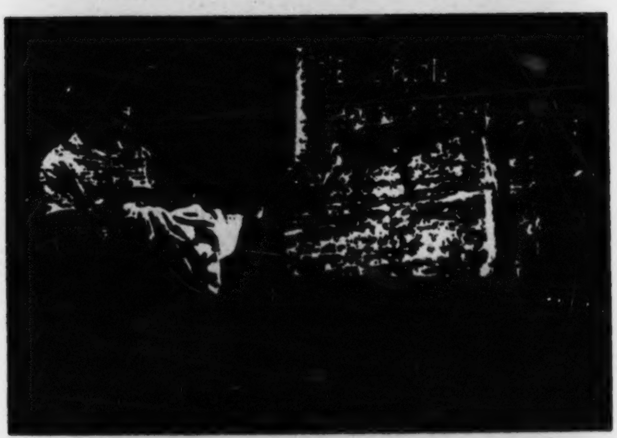
The benefits of the Dart Target System include:

- An exciting, fun-to-shoot experience during which customers experience life-size animals in life-like surroundings.
- Instant feedback on shot selection and shot placement.
- Competitions which are simple and completely objective in terms of scoring and results.
- The creation of valuable marketing lists for the retailer.
- Product advertisements from leading manufacturers to customers who are likely to purchase those products.
- An opportunity to attract young people to the shooting sports.
- A platform for distribution of information that is critical to the future of the shooting and hunting sports.



# The #1 Video Target System in the shooting sports industry combines the best of both worlds.





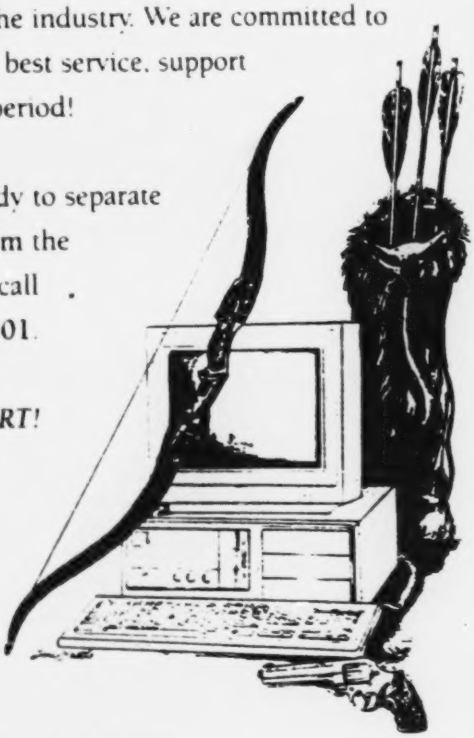
With a Dart System you can:

- ▲ Attract the two-season hunter to your shop
- ▲ Organize video leagues for all shooters
- ▲ Offer training classes on firearms safety and Bowhunter Education
- ▲ Appeal to women and young people with exciting shooting programs
- ▲ Participate in National Tournaments
- ▲ Draw from the largest library of interactive video programs on the market

At Dart we are building one of the strongest dealer networks in the industry. We are committed to providing the best service, support and quality...period!

If you are ready to separate your shop from the competition, call 1-800-745-7501.

*Shoot the DART!*



**DART**
**INTERNATIONAL, INC.**

# CORPORATE INFORMATION

**DART**
**INTERNATIONAL, INC.**

| | |
|---|---|
| Address | 1390 S. Potomac Street, Suite 100<br>Aurora, CO 80012 USA |
| Telephone | (303) 745-1600<br>1-800-745-7501 |
| FAX | (303) 745-1666 |
| Incorporated in Colorado | April 6, 1990 |
| Tax ID# | 84-1140817 |
| U.S. Patent No. | 5,328,190 |

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# TRADITIONAL ARCHERY

by
Paul Brunner

## *Tradition Meets "Hi-Tech"*

The 8th Dwarf praising something Hi-Tech? Nawwww ... you gotta be kidding, right? Nope. No joke!

I was in Pennsylvania for the opening of our first licensed Screaming Eagle store. Roger Rea, the store owner, had put in one of the new DART video target systems. I had some doubts. Those of you who read my column know that I am not exactly a fan of anything to do with technology in my beloved sport of bowhunting. You also know that I am deeply concerned about bowhunter proficiency and hunting ethically and sensibly.

After shooting one round on the DART system, I was hooked, convinced that the system was great for bowhunting, and enthusiastic about telling other bowhunters about the system.

I teach bowhunter education. In addition, I teach several bowhunting schools each year, where the students actually hunt while they are learning about all the aspects of bowhunting. The most difficult thing to teach any bowhunter regardless of his or her level of proficiency, is when to take the shot at a critter and to always pick a spot. The video target systems have changed that dramatically.

At this writing, I have only shot the DART system. There are other systems out there, but I haven't yet had the chance to shoot any of them. I can say that the DART system is really impressive. I interviewed company owners of the other video target systems and that information will follow. I guess one thing that impressed me is that a significant portion of the whitetails at which you shoot were filmed on my ranch in Montana. Some of the bucks in the system I have actually passed up on film. It's kind of neat to take the shot now and see if I would have nailed him or m-m-m-missed!

The African footage is excellent, although some of the filming was done at ranges I deem are too far to attempt with a bow. The plus-side to that, however, is to use that to teach a shooter that he or she should pass on that particular shot. There is total realism for the shooter. It's really neat to hear the doves and birds talking while you are watching a Kudu come in to a water hole.. This is the real McCoy. You are shooting at a real animal on the screen, complete with background noise, brush, and branches blowing in the breeze.

The systems available as of this writing are those made by DART, Archery Visions, and I.T.S. (Interactive Target Systems). As I mentioned earlier on, I have shot the DART system. I intend to shoot the others as soon as the opportunity presents itself.

The DART system is very impressive. The quality of the video footage and the animals is tops. The system will handle up to six shooters at a time. One of the things that I find most impressive about the DART system is the ethical message that is given the shooter who takes a poor shot. If the angle is wrong, or there is brush in the way, but the shooter takes the shot, the screen reads, "Zero points ... no shot situation!" As a bowhunter education instructor and a concerned bowhunter, I find this to be great!

I talked to Roger Rea while preparing for this article and asked him to give me his impressions of the DART system now that he has had it in his store for a year. Roger's first comment was about the fact that the video shooting systems teach the bowhunters to *pick a spot*. Really important for the bowhunter! After 38 years of bowhunting, that is still my number one problem when a big critter steps in front of me. I found that in a week of shooting the video system, I was *always* picking a spot. Roger's second comment was the same as mine above ... the ethical message for poor shots taken. His third comment was that the video system goes a long way towards teaching the shooter the exact location of the vitals, which are flashed on the animal when hit. The exact location of the arrow hit is also shown, which Roger feels is a big plus. Roger informed me that DART is upgrading their system constantly and will soon go from circles on the vitals to actual diagrams of the heart lung area.

One other interesting fact that Roger mentioned, and that I have actually witnessed while shooting in his store, is missed opportunities due to certain types of equipment. Before I go any further, remember that I am not anti-compound, or anti-sights. I have stated that repeatedly. I have also stated that I think some of the gadgetry limits or handicaps the bowhunter. These are just opinions ... so read on.

The shooters who were using releases and sights, and especially those who were used to shooting in 3-D tournaments, were sometimes not getting their shots off before the animal walked off the screen. The common request was for Roger to "slow the system down so that they could have more time to hold, aim, and squeeze the trigger." It took some explaining on both our parts to tell these shooters that this is the way the critters are naturally. You can't make a deer or elk walk slower, turn a certain way, or stand just so! It represents a *REAL HUNTING SITUATION*, something that 3-D targets don't do. I guess that's why I am so impressed with the video shooting systems in general.

Archery Visions' system is quite a bit different from the DART system in that the shooter may use any head, including broadheads, while the other systems require the use of a steel blunt. The film is projected on to a backdrop that will take hits from arrows. The animal stops over a predetermined spot where the vitals are located in the computer set-up. This system can be judged by a line judge for competition purposes. Archery Visions has 155 systems up and running around the country already. Archery Visions' system is the least expensive of all the systems, so the most affordable for the smaller shop/range owner.

I.T.S. (Interactive Target Systems) offers 3 models: the Model 50, the Model 200, and the Model 300. The Model 50 offers group shooting of up to 6 shooters in rotation. The model 200 offers the same, plus the calculation of arrow speed at the time of the hit. The Model 300 offers all of that and the additional ability for three shooters to shoot simultaneously. When the hit occurs, a realistic kill zone shape is flashed on the screen, along with the score and the arrow speed. I.T.S. has 125 systems up and running around the country.

The purpose of this column is not to tell you that one of the systems is better than another. Since I have not shot two of the systems, I couldn't do that even if I wanted to ... and I don't! I wanted to point out the benefits of the video systems to bowhunters, both beginners and experienced bowhunters alike.

I think that all of us, as bowhunters, realize that we are under a great deal of pressure from anti-hunters. We *should* all know that part of the problem is us! You bet! Every time someone goes afield with a bow in hand who is not prepared and well-practiced, we have the potential for a wounded animal. Everything possible must be done to eliminate that possibility completely. Bowhunter education is one of the ways to teach. Seminars and clinics are other teaching vehicles. Video target systems, in my opinion, rank very high in their ability to teach bowhunters when to shoot and where to shoot.

If you haven't shot one of the video systems yet, I would strongly recommend it. It's a tremendous practice tool and it's really fun. You can shoot it alone for practice, or you can shoot it in competition. I prefer just shooting with a couple of friends and comparing how we shoot ... not for score, but to see how we would have done in the woods ... where it counts!

*Hasta La Vista*
*"The 8th Dwarf"* ◁

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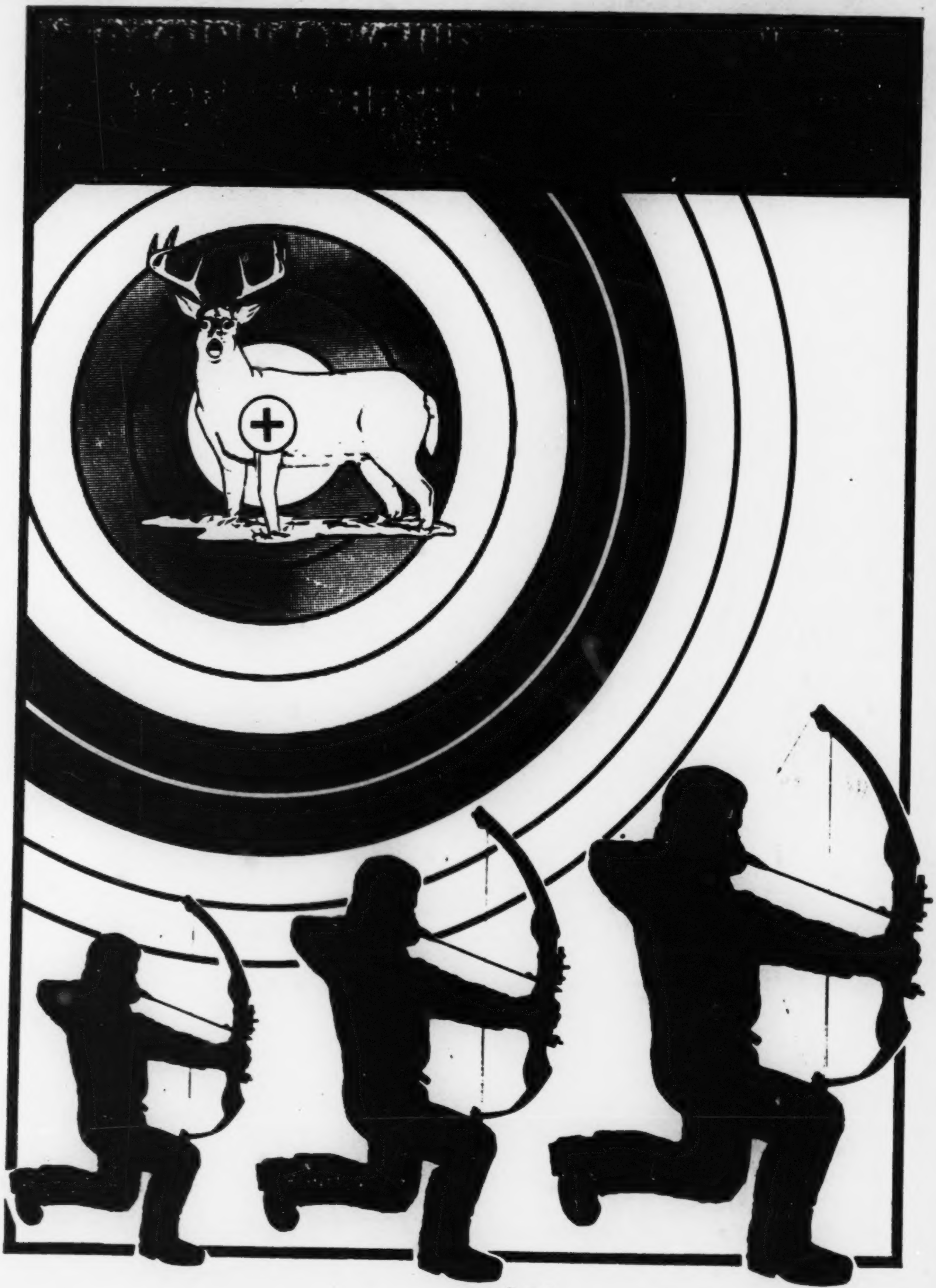
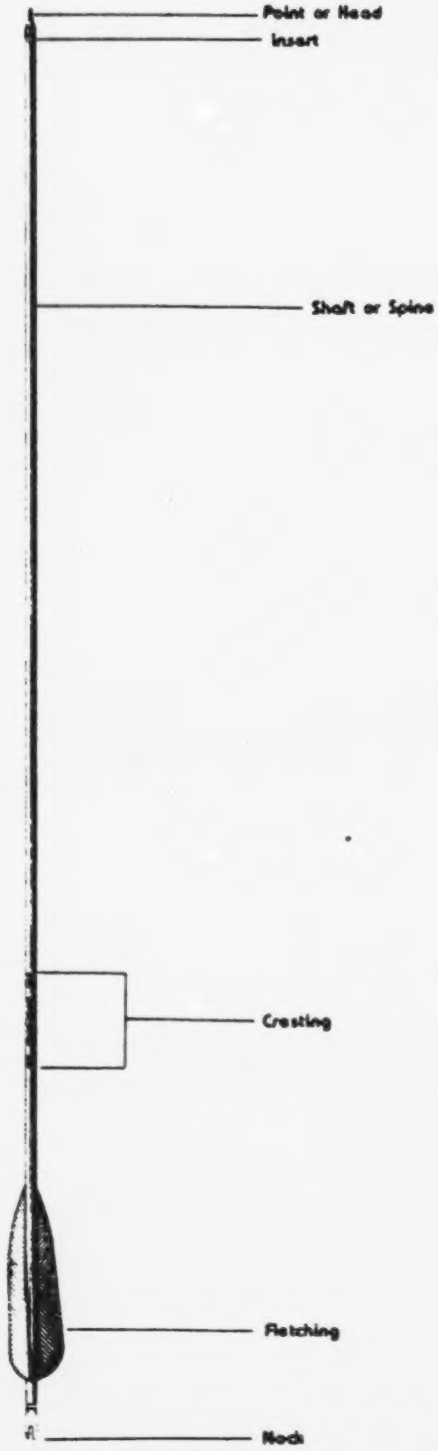


# ARROW NOMENCLATURE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Nock

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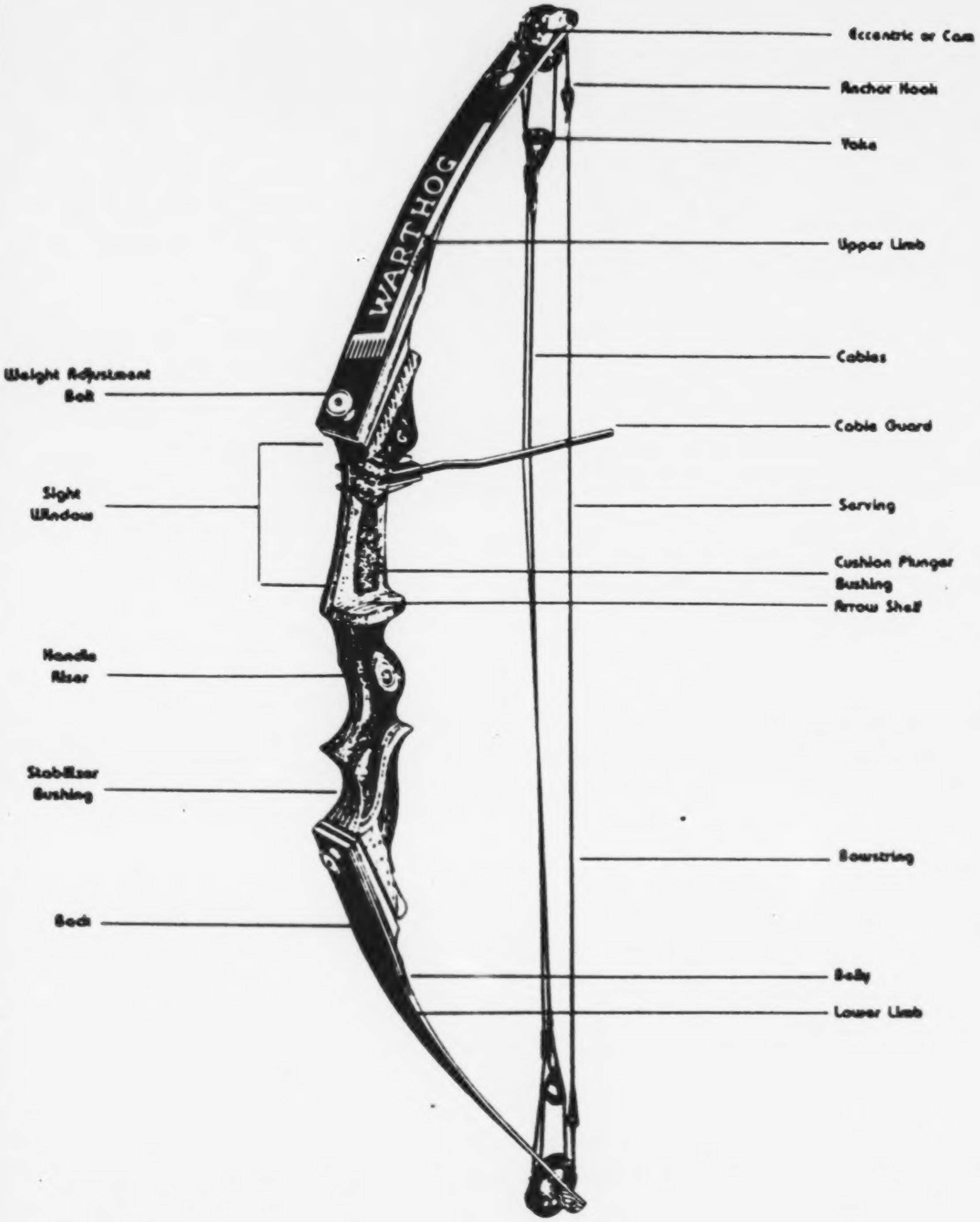
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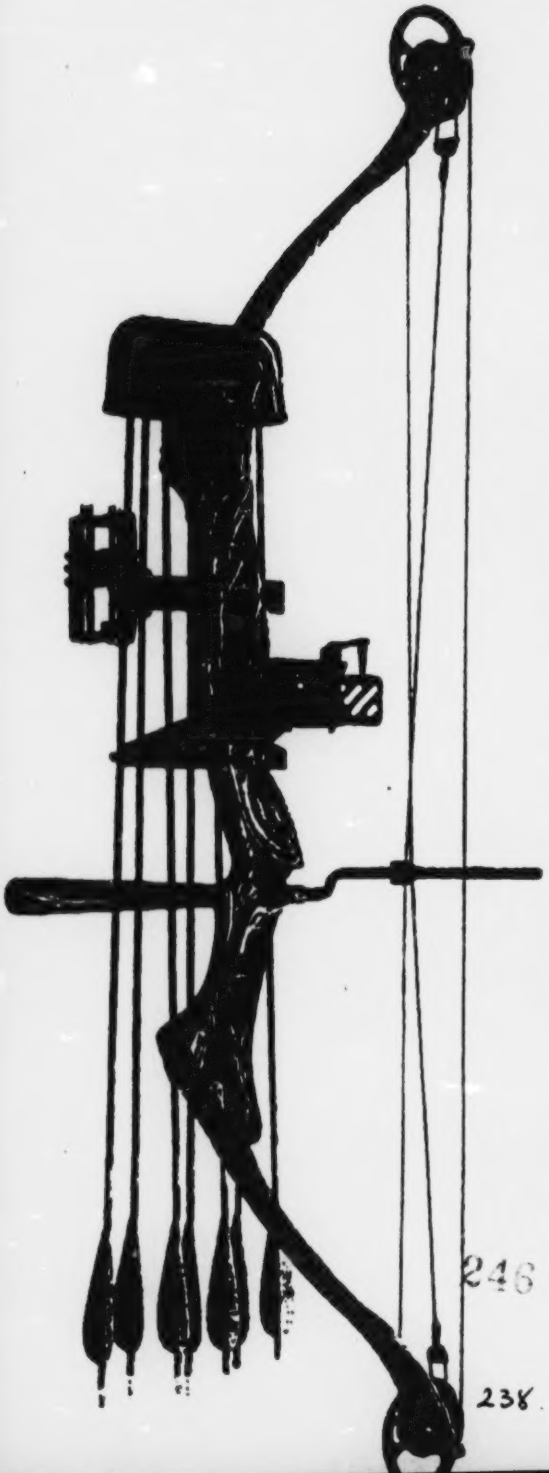
# BROWNING BALLISTIC MIRAGE

**The latest version of Browning's very successful Mirage series of bows is the Ballistic Mirage. Using the existing handle and limbs, they mounted a cam with improved performance and simplified the rigging with a new yoke and an axle-mounted cable adjustment. The result is an exceptionally fine bow, one-quarter pound lighter than the original and at least 5 feet per second faster.**



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238.

The Ballistic Mirage is built on Browning's "Magnesium Overdraw SpeedRiser." This handle is a reflexed design with the low point of the grip set about 1 1/8 inches back from a line through the centers of the limb pivot bearings. The overall length of the handle is 22 1/2 inches, with the limb pivots located about 21 3/4 inches apart. The sight window is cut 1/4 inch past center and has a usable length of about 6 inches. The offset at the arrow pass adds another 1/4 inch of clearance, making a total of 1/2 inch, measured from the centerline of the handle.

The shooting string is offset 3/16 inch from the centerline of the limbs toward the bow-arm side. This provides a total clearance of 11/16 inch, measured from the surface of the arrow pass offset to the centerline of the string. The centerline of the plunger hole is located approximately one inch above the shelf and is very close to a vertical line through the low point of the grip. There is generous clearance for both broadheads and fletching.

The mounting holes for a cable guard rod and/or other accessories are positioned opposite each other below the grip. Each is equipped with a tapped steel bushing. The standard AMO two-hole sight mounting pattern is located on the off-side of the upper riser. The pockets for the limb butts are three-sided with a closed base.

The replaceable grip is made from laminated wood in a medium wrist design. It is centered laterally on the handle.

The limbs for the Ballistic Mirage are a recurved-reflexed design. Reflexing the limbs increases the level of pre-stress obtained when the bow is at brace height. The construction features eight layers of laminations that are primarily fiberglass-reinforced, epoxy matrix material, but includes a lamination of graphite-reinforced epoxy under the backing glass. This is a totally synthetic composite which is not affected by moisture or humidity. This technique for limb construction is ideal for highly stressed, high-performance recurved limbs for compounds equipped with aggressive cams. It is tough, durable and efficient.

The planform of the limbs is a reverse taper, with the greatest width at the tips and the smallest width at the butts. It is not a straight taper; rather, it approaches a parallel outline in the slot section. The limbs have very short primary working lengths, typical of the hinged-limb design found on many compound bows. The thickness is maximum at the butt and tapers well out into the length of the limb. The recurved outer section has a relatively uniform thickness to a point just beyond the base of the slot. At this point, the thickness tapers slowly toward the center of the limb.

The overall length of each limb is 16 inches. The slot for the cam is located on the centerline and is essentially straight-sided with an elliptical base. The Ballistic Mirage uses semi-cylindrical limb pivot bearings which are doweled into the face of the limb butts. These pivot bearings fit into matching sockets in the ends of the handle.

The Ballistic Plus cam is similar in most respects to the other Browning cams. Part of the cable track is a rotating element that can be set in various positions to effect change in draw length. Some Browning cams also permit altering the percent of let-off, but this is not true of the Ballistic Plus cam. The base cam has the string-side track as its perimeter, and the fixed section of the cable-side track is machined integral with base. In addition, a circular hub projects into the plane of the cable-side track. This hub is used to support the adjustable section of the cable track.

Browning calls this rotating adjustable section the "inner cam." Part of the periphery of the inner cam is circular and matches the inside surface of the fixed section of the cable track. The inner cam can be set in any of three positions to provide three different draw lengths in one-inch increments. It is fixed in the elected position by two flat-head, socket-type screws. The three positions are designated by the letters "A", "B" and "C". There is an index mark on the fixed track to aid in positioning the inner cam. The base cam is machined from aluminum alloy, while the inner cam is molded from reinforced structural plastic.

There is a diecast double-headed pin, called a cable-lock, pressed into a hole in the central area of the base cam. This cable-lock projects on both sides and is used to anchor the string on one side and the cable on the other side. The fixed section of the cable track controls the force-draw characteristic from brace height to approximately 20 inches draw length. At this point the cable leaves the fixed track and transfers to the track of the inner cam.

The cable actually bridges a gap in the two tracks by stretching straight across the gap, effectively creating a flat spot in the cam track. This flat spot covers about two inches of the draw from 20 to 22 inches. The effect can be seen as a dimple or dip in the force-draw curve. Considering the design of the cam with its rotating inner cam, it would be very difficult to eliminate this transition area and still maintain the structural integrity of the end of the fixed track. While I was able to show the dip effect with instrument readings, I found it hard to find when drawing the bow by hand. Browning uses two cam sizes to provide draw length ranges of 28 to 30 inches and 30 to 32 inches. The cams are fitted with acetal alloy bearings.

The rigging of the Ballistic Mirage has been greatly simplified, at least visually, from that of the original Mirage that uses the torque synchronizer system. The Ballistic Mirage is equipped with Browning's new axle synchronizers which eliminate the multiple cable runs that the torque synchronizers required. Instead, the normal cable run is attached to a yoke fitting which is suspended from the axle by means of a short cable equipped with diecast end fittings. The axle passes through one end fitting while the other fitting is pinned to a slotted clevis that is fitted over the axle. The position of the clevis with respect to the axle can be adjusted by a set screw set in the end of the clevis. The set screw has a locknut that keeps the screw from backing out once the cams have been properly synchronized.

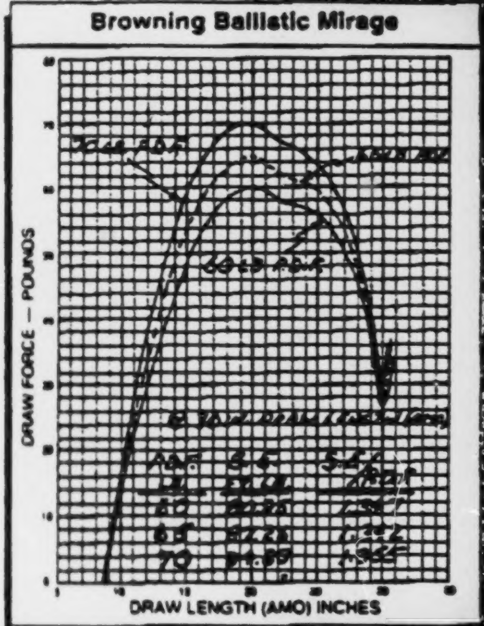
Since only one end of the yoke cable is adjustable, the change in the effective length of the main cable is one-half the length that the set screw is moved. I feel that this arrangement is a significant improvement over the prior rigging since it minimizes weight at the ends of the limbs, thus enhancing performance. In addition, I believe that its simplified form also increases the integrity of the rigging as well as improving the overall appearance of the bow.

## PERFORMANCE PROFILE

| | |
|---|---|
| Rating Velocity | 232.2 feet per second |
| Stored Energy | 80.85 foot pounds |
| Holding Force @ 30 inches | 26.8 pounds |
| Draw Force Reduction (let-off) | 55.3 percent |
| Mass Weight | 4 pounds, 5 1/4 ounces |
| Brace Height | 6 15/16 inches |
| Average Virtual Mass | 133.6 grains |
| Cam System | Ballistic Plus-3DL |

(Tested at 60 pounds)

FIGURE



Force-draw curves obtained from [illegible] the static tests at all three test conditions.

**Norb Mullaney** has [illegible] *Bowhunting World* fo[illegible] master's degrees in mech[illegible] aeronautical engineering [illegible] Engineer in the state of Wisconsin.

Mullaney's lifelong [illegible] design, build and experiment [illegible] equipment. He acts as [illegible] Manufacturers Organization and [illegible] Subcommittee respo[illegible] archery products, as well [illegible] Safety and Standards Committee.

Mullaney also has been [illegible] 35 years and is currently [illegible] Bowhunters Association.

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The bowstring is an 18-strand, Fast Flight, endless loop type with a monofilament center serving. The 28- to 30-inch draw length requires a string length of 58 1/4 inches, while the 30- to 32-inch draw length calls for a string length of 61 3/4 inches.

The cable guard is a 3/8-inch diameter round steel rod with a slick black finish. It is dog-legged to provide adjustment of cable clearance. The rod is threaded into the bushing located on the face of the lower riser below the grip and locked after being adjusted for the desired clearance using a tapered ferrule jam nut.

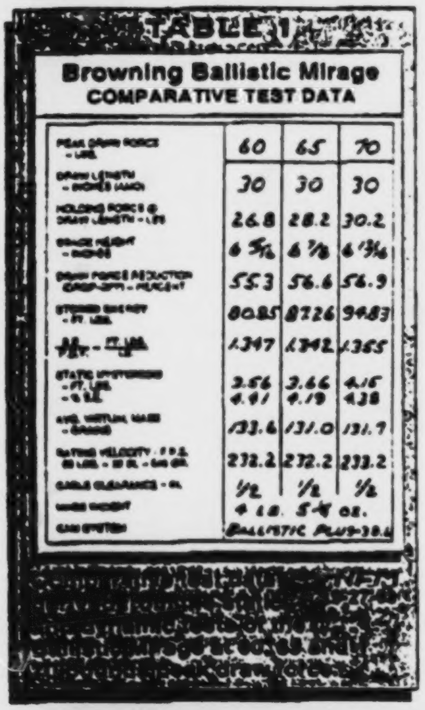


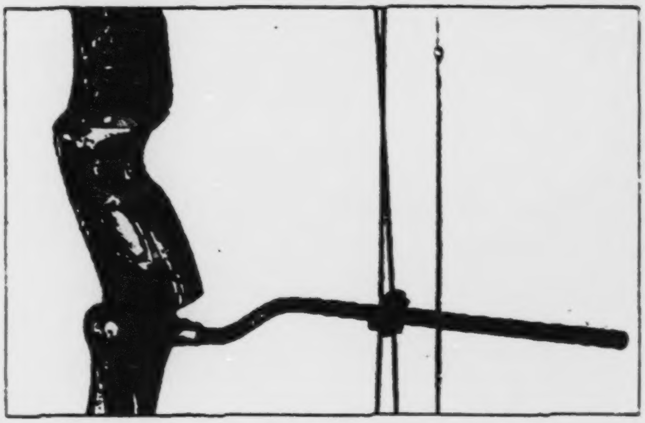
TABLE 1

**Browning Ballistic Mirage**
**COMPARATIVE TEST DATA**

| | | | |
|---|---|---|---|
| PEAK DRAW FORCE – LBS. | 60 | 65 | 70 |
| DRAW LENGTH – INCHES (AMO) | 30 | 30 | 30 |
| HOLDING FORCE @ DRAW LENGTH – LBS | 26.8 | 28.2 | 30.2 |
| BRACE HEIGHT – INCHES | 6 5/16 | 6 7/8 | 6 13/16 |
| DRAW FORCE REDUCTION (LET-OFF) – PERCENT | 55.3 | 56.6 | 56.9 |
| STORED ENERGY – FT. LBS. | 80.85 | 87.26 | 94.83 |
| S.E./P.D.F. – FT. LBS./LB. | 1.347 | 1.342 | 1.365 |
| STATIC HYSTERESIS – FT. LBS. – % S.E. | 3.56<br>4.41 | 3.66<br>4.19 | 4.15<br>4.38 |
| AVG. VIRTUAL MASS – GRAINS | 133.6 | 131.0 | 131.7 |
| RATING VELOCITY – F.P.S. 60 LBS. – 30 IN. – 540 GR. | 232.2 | 232.2 | 233.2 |
| CABLE CLEARANCE – IN. | 1/2 | 1/2 | 1/2 |
| MASS WEIGHT | 4 LB. 5 1/4 OZ. | | |
| CAM SYSTEM | BALLISTIC PLUS-30.4 | | |

A Browning "FreeWheel Roller Guide" carries the cables on the inside of the guard rod. The roller guide has a large wheel with a "V" groove that rides on the outside of the rod. The base of the "V" groove has a narrow and deeper groove that is fitted with an "O" ring that projects into the base of the "V" sufficiently to cause it to be slightly compressed. This provides elastic loading against the lateral pull of the cables to eliminate chatter.

The roller has an integral axle which fits into slots in two arms of the carrier element. The carrier, which has a "U" shape, surrounds the guard rod with its closed end. The closed end of the "U" has a hub on either side oriented parallel with the guard rod. These hubs are through-drilled and a roll-pin is pressed into the hole flush with both ends of the hub. The hubs are slotted to expose the roll-pin which contacts the cables as they move through the roller assembly. The unit retains the cables securely and has a very smooth action. I have used this roller cable carrier in the field many times and never experienced a problem.



**The FreeWheel cable roller guide and the laminated wood grip are standard equipment on the Ballistic Mirage.**

The Ballistic Mirage is offered in two camouflage patterns, Mossy Oak Treestand and Deep Forest. In addition, there is a 3-D model available in basic silver highlighted in jade, red or blue, with color-coordinated limbs and chrome hardware. Adjustable draw weight ranges are 45 to 70 pounds and 60 to 80 pounds.

## The Tests

The test bow was rated at 45 - 70 pounds peak draw force, with a draw length adjustable between 28 and 30 inches. I equipped the bow with a Centerest arrowrest and tuned the setup for some hand shooting. One thing that impressed me immediately was the low noise level. Despite the very obvious high arrow velocity, the bow was very quiet. After the hand shooting session, I decided to test at three peak draw forces of 60, 65 and 70 pounds with a common draw length of 30 inches AMO. This is a somewhat higher range of peak draw force than the usual test format, but because this bow had a top draw weight of 70 pounds, I felt that the higher level would provide a better appraisal of its performance. After all, a 25-pound adjustable range for draw weight is unusual.

The static tests are run using a force-draw machine equipped with a digital force gage that measures draw force to the nearest one-tenth pound. Draw force is read in one-inch increments as the bow is drawn from brace height to the test draw length, in this instance 30 inches AMO. Stored energy is calculated from these data and other static measurements are also obtained.

The force-draw curves are presented in Figure 1 along with values of stored energy and the ratio of stored energy to peak draw force (S.E./P.D.F.) for each of the selected draw weights. The transition area peculiar to this design of cam is evident on each of the curves near the beginning of the let-off slope. However, as stated earlier, I found this dimple or dip difficult to feel while drawing the bow by hand. While only the force-draw curves are shown, the let-down curves demonstrate the same characteristic. The

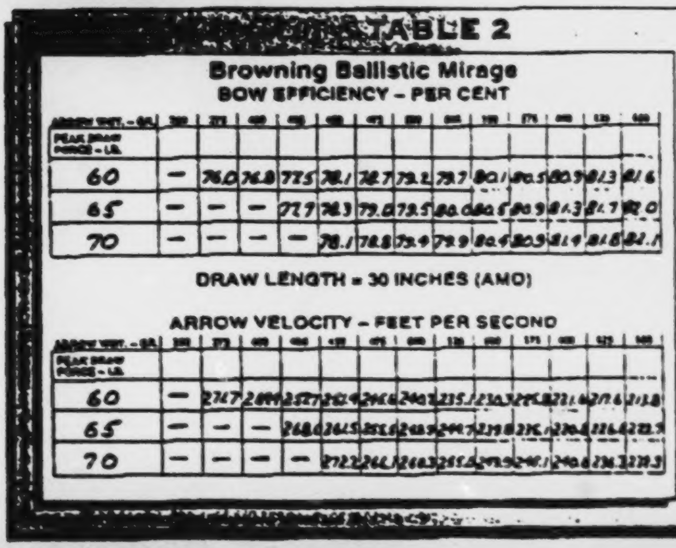


TABLE 2

**Browning Ballistic Mirage**
**BOW EFFICIENCY – PER CENT**

| ARROW WGT. – GR. | 350 | 375 | 400 | 425 | 450 | 475 | 500 | 525 | 550 | 575 | 600 | 625 | 650 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PEAK DRAW FORCE – LB. | | | | | | | | | | | | | |
| 60 | — | 76.0 | 76.8 | 77.5 | 78.1 | 78.7 | 79.2 | 79.7 | 80.1 | 80.5 | 80.9 | 81.3 | 81.6 |
| 65 | — | — | — | 77.7 | 78.3 | 79.0 | 79.5 | 80.0 | 80.5 | 80.9 | 81.3 | 81.7 | 82.0 |
| 70 | — | — | — | — | 78.1 | 78.8 | 79.4 | 79.9 | 80.4 | 80.9 | 81.4 | 81.8 | 82.1 |

DRAW LENGTH = 30 INCHES (AMO)

**ARROW VELOCITY – FEET PER SECOND**

| ARROW WGT. – GR. | 350 | 375 | 400 | 425 | 450 | 475 | 500 | 525 | 550 | 575 | 600 | 625 | 650 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PEAK DRAW FORCE – LB. | | | | | | | | | | | | | |
| 60 | — | 274.7 | [illegible] | 252.7 | [illegible] | 246.6 | 240.3 | 235.1 | 230.3 | 225.8 | 221.6 | 217.6 | 213.8 |
| 65 | — | — | — | 268.0 | 261.5 | 255.5 | 248.9 | 244.7 | 239.8 | 235.1 | 230.4 | 226.4 | 222.5 |
| 70 | — | — | — | — | 272.2 | 266.1 | 260.5 | 255.4 | [illegible] | 246.1 | 240.6 | 236.3 | 231.5 |

**Values of bow or dynamic efficiency and initial arrow velocity for a wide range of arrow weight at the three levels of draw weight.**

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**The diecast magnesium alloy Overdraw SpeedRiser has lightening holes machined in the sides of the limb pockets.**

draw and let-down are quite smooth, and the bottom-of-the-valley is precisely located at 30 inches draw length. This bow has a very short valley with a pronounced wall as draw length is increased. It should please any compound shooter who likes to draw into the "stops."

Stored energy levels are excellent, with 80.85 foot-pounds at a peak draw force of 60 pounds, 87.26 foot-pounds at 65 pounds, and 94.83 foot-pounds at 70 pounds. The ratios of stored energy to peak draw force were 1.347, 1.342 and 1.355 foot-pounds per pound, at 60, 65 and 70 pounds respectively.

Table 1 lists comparative data for the three test conditions. The first nine lines are from the static tests. Brace height changed only 1/8 inch as draw weight was increased from 60 to 70 pounds. Let-off ranged from 55.3 to 56.9 percent, increasing slightly as draw weight was raised. Static hysteresis, which is a measure of friction in the bow and its components, is unusually low, ranging from 4.19 to 4.41 percent of stored energy. This, along with the high levels of stored energy, forecasts good performance.

Dynamic tests are performed with the bow mounted in a shooting machine in order to insure consistency from shot to shot. Arrow velocity is measured by a double chronograph arrangement. The two instruments are set in tandem, with the first unit located 3 feet down-range from the back of the bow. Six test arrows, varying in weight in approximate 50-grain increments from about 400 to 650 grains, are each shot a minimum of five times in order to establish credible average values of velocity. These experimental average velocity values are used to derive a curve of virtual mass versus arrow weight. From this curve, arrow velocity can be calculated for any desired

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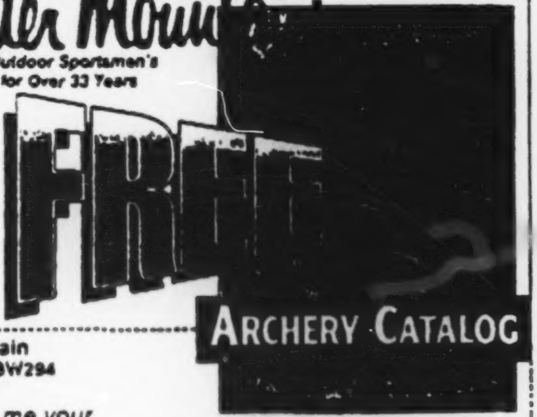

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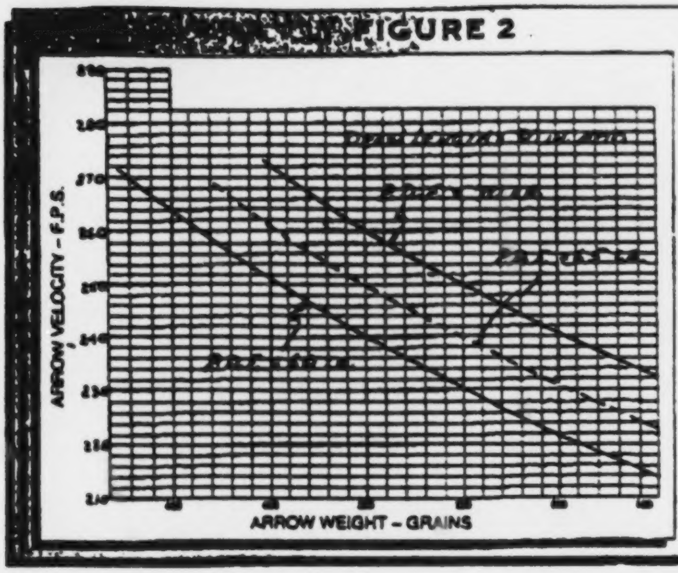
FIGURE 2



Series of curves of initial arrow velocity plotted versus arrow weight taken from the data in Table 2.

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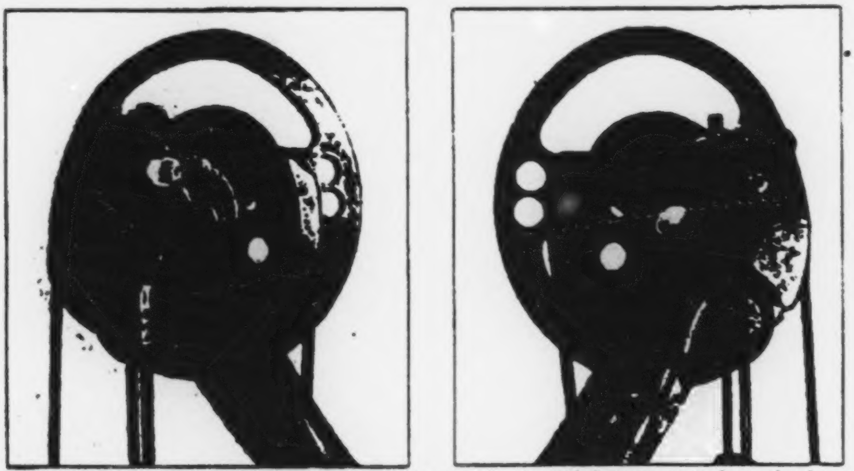
arrow weight. The lower section of Table 2 lists values of initial arrow velocity for a wide range of arrow weight in increments of 25 grains.

The initial arrow velocity values tabulated in Table 2 are presented in graphic form in Figure 2. Here the velocity is plotted versus arrow weight, with a separate curve for each draw weight tested. While the curves look quite parallel, they are actually divergent. The difference in velocity corresponding to a 5-pound change in draw weight for a given heavy arrow is less than that for a given light weight arrow. This is readily observed by referring to the tabulated values in Table 2.



The Ballistic Plus cams incorporate three draw length increments in a single rotating inner cam element.

Once the arrow velocity has been obtained, the kinetic energy possessed by the arrow can be calculated, since the weight of the arrow is known. Kinetic energy is the energy possessed by the speeding arrow by reason of its mass and velocity. The kinetic energy is a measure of the penetration potential of the arrow, all else being equal.

Table 3 presents curves of initial kinetic energy plotted versus arrow weight for the three levels of draw weight tested. Observe that at all values of arrow weight, the ratio of kinetic energy to peak draw force is greater than unity for all three draw weights. This ratio, which I call the power factor, is a measure of the overall efficiency of the system. The system includes the bow, the arrow, the draw length and the personal form and efficiency of the archer. In this case, the archer is a shooting machine with almost perfect form and efficiency. The results of thousands of tests of archers and their equipment over a number of years has shown that a power factor of 1.00 (unity) or greater represents an exceptionally good combination. An average value of the power factor is in the neighborhood of 0.843.

244 Power factor is improved by a bow with better performance, a heavier arrow, a longer draw length or a more efficient archer. For the Ballistic Mirage, using an arrow weight of 540 grains, a draw length of 30 inches AMO, and our very efficient shooting machine, the power factors are 1.078, 1.078 and 1.087 at 60, 65 and 70 pounds respectively. The bow's exceptional performance means there is room there for those of us with shorter draw lengths and less efficient execution!

The bow or dynamic efficiency of the bow and arrow combination is obtained by expressing the kinetic energy of the arrow as a percentage of the stored energy of the bow. In essence, it is what we get out for what we put in. Since we have determined the initial kinetic energy of the arrow, it is a simple matter to calculate the dynamic efficiency of the bow when used with each weight of arrow. The first section of Table 2 lists the dynamic efficiency values corresponding to the arrow weights and velocity values shown. As indicated earlier by the static hysteresis, dynamic efficiency is very good, exceeding the 80 percentile level for all three draw weights at an arrow weight of 550 grains.

The rating velocity is a standard performance parameter established by AMO to permit comparison of bows. It is defined as the initial velocity of a 540-grain arrow shot from a bow set at 60 pounds peak or maximum draw weight and 30 inches AMO draw length. I determine the rating velocity from the curve of arrow velocity versus arrow weight established by the method described earlier. When the bow is tested at other than 60 pounds, the rating velocity is corrected mathematically to provide a comparative value.

Table 1 lists the rating velocities obtained for the test Ballistic Mirage at 60, 65 and 70 pounds. The rating velocity at 60 pounds, 232.2 feet per second, is the significant parameter. The other two are only for comparison. In essence, they show that relative performance is identical at 65 pounds draw weight (232.2 feet per second) and slightly better at 70 pounds (233.2 feet per second). This is quite believable, since the energy storage efficiency is improved at the high draw weight and the dynamic efficiency is very similar.

The virtual mass is another parameter that displays the efficiency of a bow and arrow combination. It functions inversely to the dynamic efficiency since the lower the virtual mass, the higher the dynamic efficiency. The Ballistic Mirage has an exceptionally low level of average virtual mass, ranging from 131.0 to 133.6 grains. The virtual mass can be readily understood if it is visualized as an imaginary mass that represents all of the inefficiencies of the bow and arrow combination. It is further imagined as being shot from the bow at the same velocity and at the same instant that the arrow is discharged. It is unusual to find a compound bow with an average virtual mass below 140 grains.

The Ballistic Mirage offers a very high level of performance no matter which parameter is used for comparison.

## General Commentary

The axle-to-axle length of the test bow measured 41 1/4 inches. It did not change when the draw weight was changed within the range tested. The included angle of the string was 89 1/2 degrees with a draw length of 30 inches AMO. Cable clearance was set at 1/2 inch, measured from a 5/16-diameter shaft set in the plane of the string to the nearest cable.

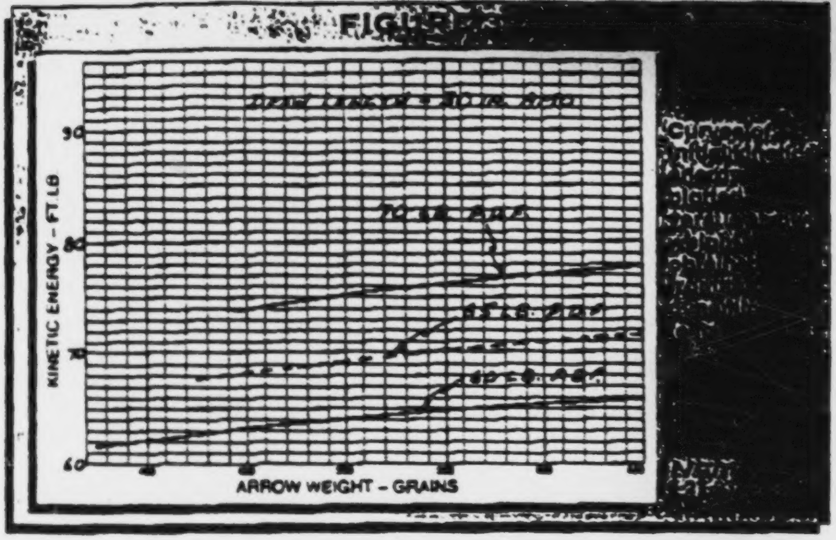
It is interesting to compare the Ballistic Mirage to the Mirage I tested in 1990. The Ballistic, with its new cams, stores about 2 foot-pounds more energy at the same draw weight than the earlier bow did. The static hysteresis is lower by about 2 foot-pounds, and the dynamic efficiency is about 2 percent higher for equivalent arrow weights. The average virtual mass has been reduced by 16 to 18 grains. The rating velocity has been increased by over 5 feet per second. The draw is smoother and just as easy for a given draw weight, and the weight-in-hand is 1/4 pound less.

With the new rigging, the Ballistic looks less complex and certainly more attractive. If all of that doesn't push you to trade in your old Mirage, I miss my guess. I must admit that I prefer the old molded grip to the new wood grip. It is narrower through the throat and seems to fit my bow-hand better.

I found the Ballistic Mirage to have excellent shooting qualities. It tuned without difficulty, is a very quiet bow, and delivers an arrow with a great deal of authority. For a bow with such high performance, it is smooth and easy to draw and pleasant to shoot.

Changing draw length is a matter of removing the two screws that hold the inner cam in place, rotating the cam to the desired position and replacing the screws. The screws are readily accessible, but the manufacturer cautions against over-tightening them. Too much pressure from the taper on the underside of the head of the screw can break the inner cam. The cable load on the inner cam is taken by the hub and fixed track on the base cam, and not by the attaching screws. It is only necessary to tighten them sufficiently to hold the inner cam against rotation.

In my judgment, the Ballistic Mirage is an excellent hunting bow and should prove to be a real contender in 3-D shooting.



**The alloy axle synchronizer permits fine tuning of cam roll-over to obtain perfect synchronization. A special pin lock holds components together.**

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243 251

# ARCHERY

## Product Knowledge— Basic Information On The Art Of Selling Archery Equipment

written by

John Spomer

published by

National Sporting Goods Association
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Chicago, Illinois 60611

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Both types are made for either tournament or hunting shooting with some models that may be used for either sport.

The handle riser on take-down bows may be of magnesium or an alloy of magnesium and aluminum, or of laminated and dyed maple or of solid hardwood.

The better quality bows have perfectly matched limbs of laminated maple and fiberglass construction in the recurve style. The limbs are sold in pairs and the archer may purchase several pairs of limbs, in weights and lengths for tournament shooting or hunting for use on the same handle.

Moderately priced take-down bows may have solid wood handles and solid fiberglass recurved limbs. Limbs may also be interchanged in this quality.

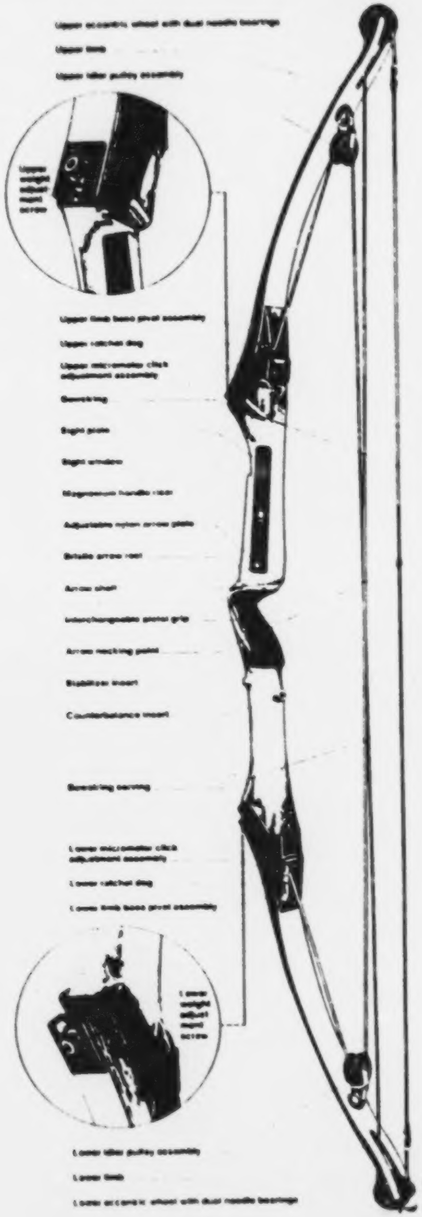
Many experienced archers prefer take-down bows because they are more stable when shooting than composite bows, are easily carried and stored, and are suitable for any type shooting by simply changing the limbs.

One variation in take-down bows has a wood handle riser with an aluminum locking device and pin in the center of the handle for take-down. The limbs of this bow are permanently molded to each handle section. In appearance this bow is very similar to a conventional composite bow.

## The Compound Bow — How It Works — Three Principles

The compound bow is a new concept that promises to solve bow-weight problems and increase an archer's accuracy. The compound bow was invented and developed by Mr. H. W. Allen of Billings, Missouri. Most compound bows are manufactured by various companies under license from Mr. Allen.

### Compound Bow Terminology


Upper eccentric wheel with dual needle bearings
Upper limb
Upper idler pulley assembly
Upper limb base pivot assembly
Upper ratchet dog
Upper micrometer click adjustment assembly
Bowstring
Sight pins
Sight window
Magnesium handle riser
Adjustable nylon arrow plate
Bristle arrow rest
Arrow shelf
Interchangeable pistol grip
Arrow nocking point
Stabilizer insert
Counterbalance insert
Bowstring serving
Lower micrometer click adjustment assembly
Lower ratchet dog
Lower limb base pivot assembly
Lower idler pulley assembly
Lower limb
Lower eccentric wheel with dual needle bearings

**Increased Foot-Pounds of Energy**
A rifle with a 20" barrel produces much greater muzzle velocity (speed) than a hand gun with a 6" barrel of equal caliber, bullet weight and powder charge. The rifle applies the gas pressure for 20" rather than just 6", increasing the *foot-pounds* of energy applied to the bullet.

The eccentric pulleys on the limb tips of the compound bow accomplish this same principle by applying maximum pull weight for a *greater number of inches;* in the conventional bow, pull weight decreases from the instant of release at a steady rate as the bow string moves forward. In the compound bow, the peak pull weight poundage is at mid draw. Therefore, as the bow string moves forward from release, the poundage *increases to peak* and then decreases, giving a major increase in *foot-pounds of energy* for application to the arrow.

**Reduction of Inertia *(Resistance of Weight to Motion)***
In the rifle, the only inertia is that of the bullet. The total weight which must be put in motion in any bow, is the arrow, plus bow string, plus that portion of each bow limb which moves. In the conventional bow, each limb weighs more than twice the weight of the arrow, which means that you must move *five arrows in weight*, in order to shoot one arrow. This is why reduction of the weight of the one arrow you shoot, produces only modest speed gains. You are reducing the weight of only 1/5 of the total load. It is also why with conventional bows heavy arrows and heads are recommended for hunting penetration. Conventional bows can not increase speed to get penetration. In a 50# conventional bow, 50# must propel the weight of the limbs a distance of 8"; the same 50# must propel the center of the string and the arrow 20" to string rest position.

In compound bows, generally two strands of cable (connected to a conventional bow string) run over pulleys in a manner similar to a block and tackle, therefore with a total of three strands pulling on the limb tips, limbs must be used equal in strength to a 150# conventional bow, in order to result in a 50# pull on the string of a compound bow. The limb tip travel is reduced to only 3", rather than 8" as in the conventional bow.

Therefore, 150# is available to move limbs and pulleys a distance of only 3" while the remainder of the 50# force on the string moves only the string and arrow the normal distance of 20" to string rest position. This is why reduction of total arrow weight in a compound bow produces phenomenal speed increases of 50%. Most of the inertia of the limbs is eliminated by the tripled force applied to moving them the shorter distance they must move. Thus the arrow weight reduction is converted directly to speed increase, with little or no loss of impact or penetration.

**Reduction of Arrow Weight**

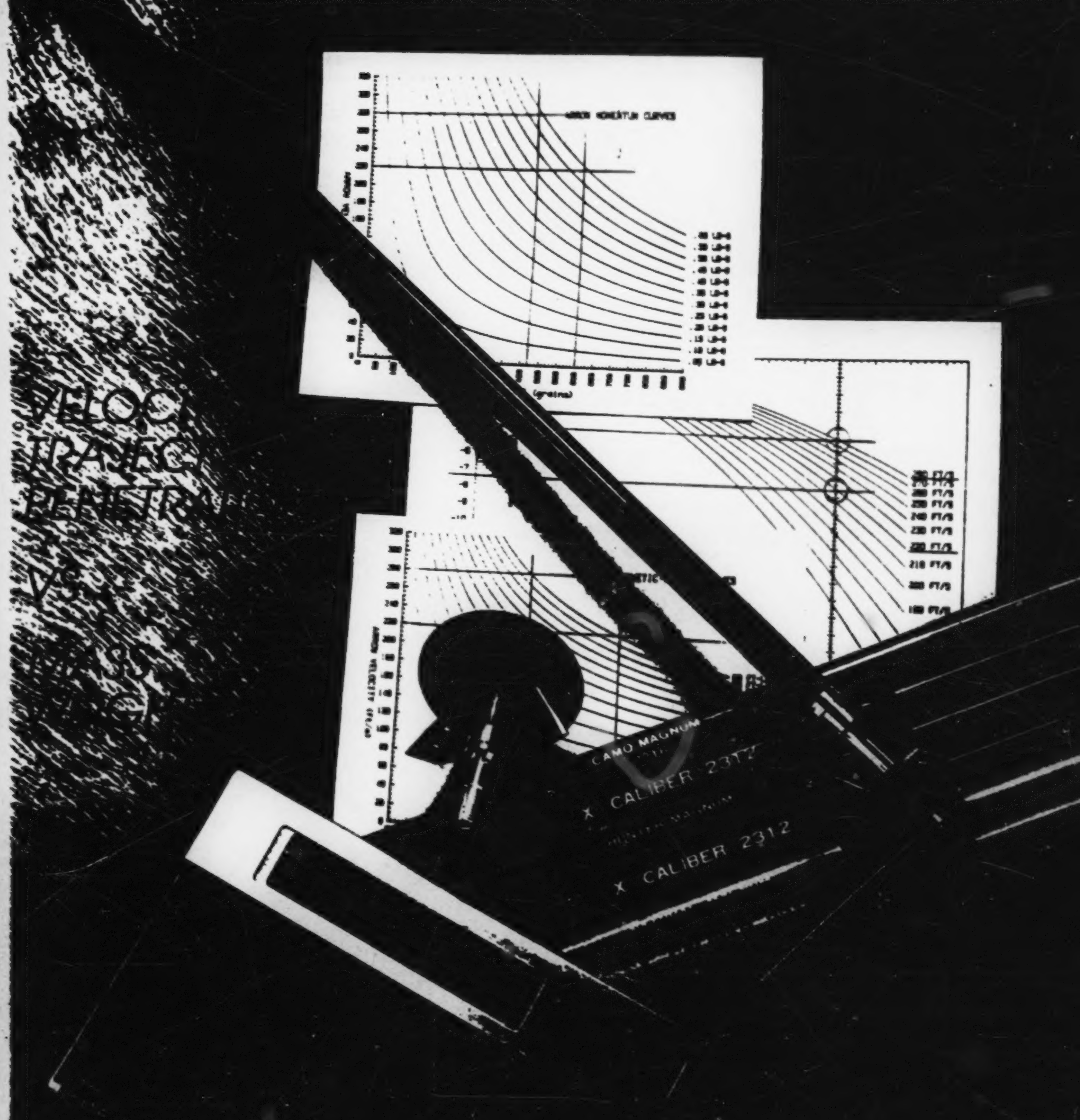
It is possible to use lighter arrows in a compound bow because of the relaxation at full draw, due to the action of the eccentric pulleys on the limb tips. Acceleration is gradual, and the arrow is in motion before peak push is applied. The relaxation is from 15% to 20% of the peak weight, meaning that a 50# peak setting on a compound bow will hold at full draw at about 40#. Therefore, an arrow spined for 40# is about what can be used. Instruction sheets for matching arrows to compound bows are included with the bow and should be followed.

Compound bows are made in either a one piece full length style or in the take-down style. Handle risers may be either magnesium or hardwood. Limbs are laminated wood and fiberglass in the top quality bows and solid fiberglass in the lower quality bows. Lower quality compound bows may be more expensive than most high quality conventional bows.

Compound bows are made by some manufacturers in both target and hunting models, some make only hunting models and some make one style that may be used for both types of shooting. Target bows range from 56" to 58" in length. Hunting bows range from 48" to 50" and bows that may be used for either type of shooting are in the 51" length range.

In most makes of compound bows the two idler wheel-pulley assemblies are attached to the bow limbs part way down the limb from the tip. The eccentric-wheel assemblies are attached at the tips of the limbs. The steel cables are attached to a conventional bow string near each tip by the use of S hooks. These bows are generally available in three target and three hunting limb weights and draw weights. Generally draw lengths can be adjusted and peak weight can be adjusted within a 10 lb. range. Mass weight of these bows will vary from 3 lb. 8 oz. to 4 lb. 4 oz.

# THE TECHNICAL TRUTH ABOUT:


VELOC
TRAJEC
PENETRA
VS
MASS
ARROW MOMENTUM CURVES
(grains)
CAMO MAGNUM
X CALIBER 2312
X CALIBER 2312

ADVANCED ARCHERY EQUIPMENT

**X-CALIBER** "The Fastest most Efficient arrow shaft in the World"

## X-CALIBER SPECIFICATIONS and COMPARABLES

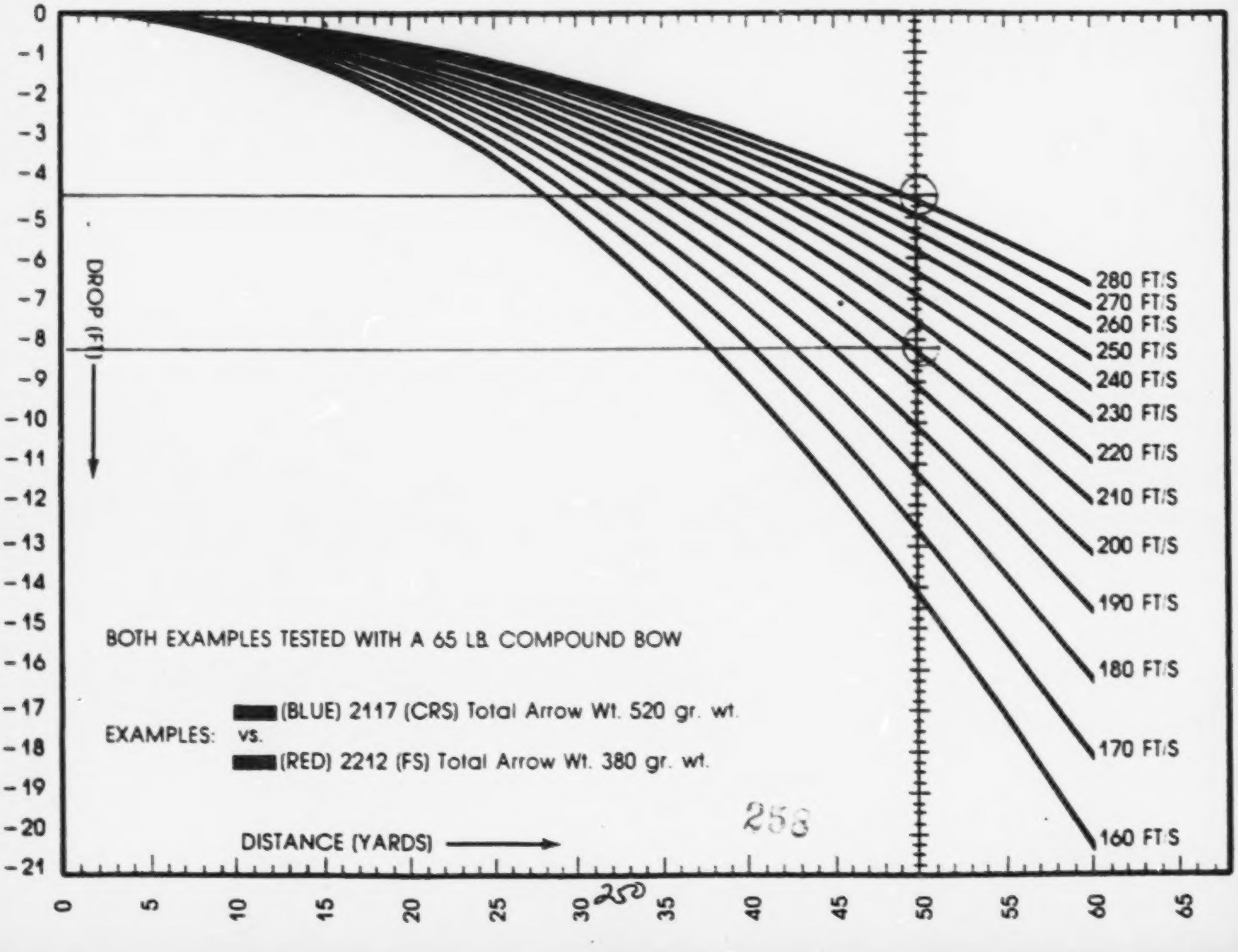
| Shafts Sizes | O.D. | I.D. | Grain Wt Per Inch | Insert Grain Wt. | FLUTE Width/Depth | DEFLECTION per 30" Centers | WALL Thickness | Comparable Aluminum Sizes |
|---|---|---|---|---|---|---|---|---|
| [illegible] | .314 | .290 | 7.7 | 13.88 | .014/.060 | .875 | .012 | 1816/1818/1916<br>1918/2013/2016 |

[redacted]

The Advanced Archery Equipment Hunting Shaft Selection Chart was designed for the experienced Bowhunter and Target Archer as well as the Novice for fast reference of arrow shaft size per Bow Weight and Draw Length. The X- CALIBER fluted arrow shaft sizes have been added to the chart for quick reference from the CONVENTIONAL ROUND ARROW SHAFT (CRS) to the FLUTED ARROW SHAFT (FS).

Note: All shaft sizes on chart (1816 through 2412) are contractions of actual physical dimensions of the tubes. Example: 2212 Fluted shafts have 22/64" outside diameter and a .012" wall thickness.

## ARROW TRAJECTORY CURVE



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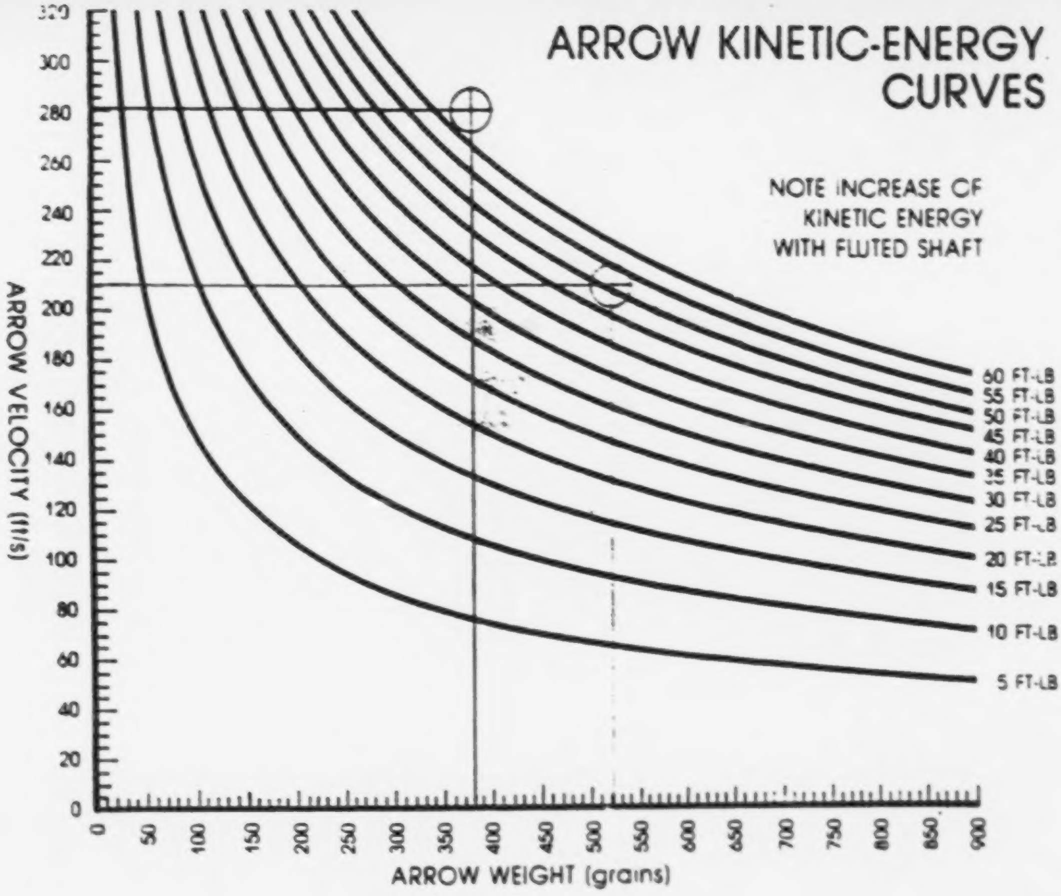
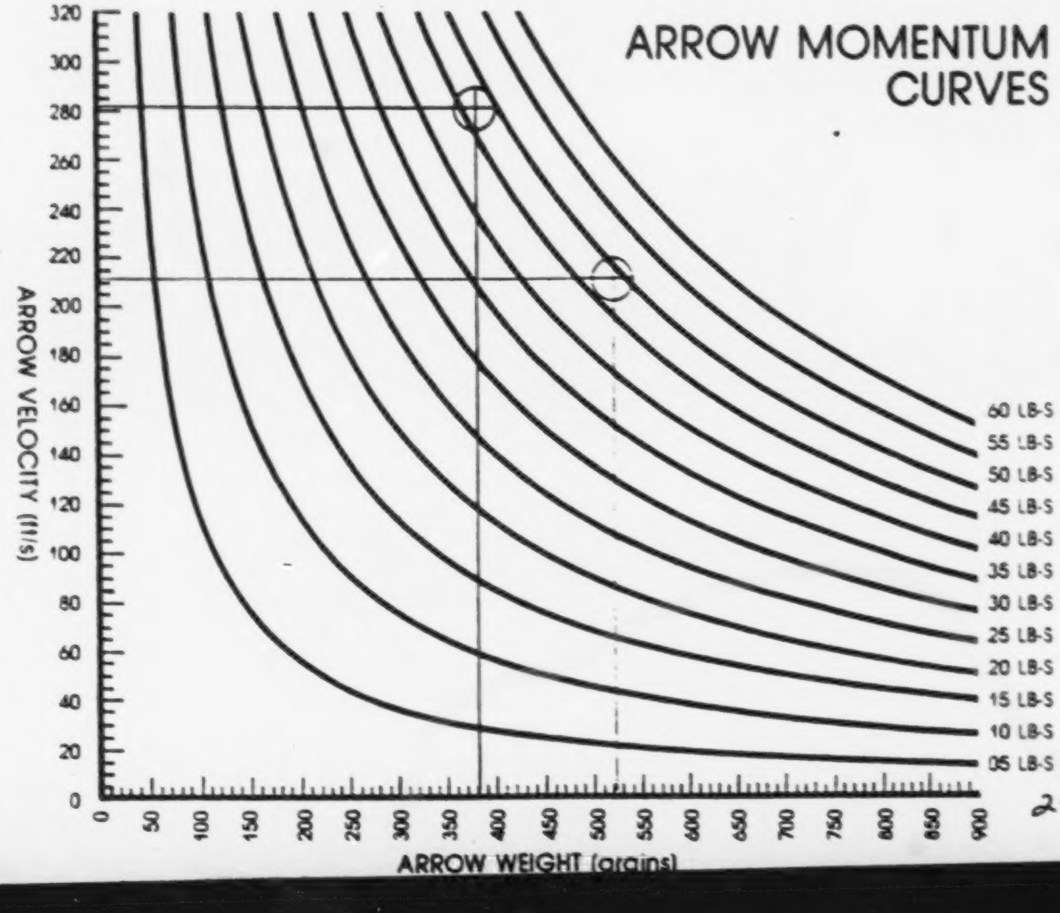
250


ARROW KINETIC-ENERGY CURVES

NOTE INCREASE OF KINETIC ENERGY WITH FLUTED SHAFT


ARROW MOMENTUM CURVES

# ADVANCED ARCHERY EQUIPMENT HUNTING SHAFT SELECTION CHART

| Actual Bow Weight | ACTUAL HUNTING ARROW LENGTH | | | | | | | | | | | | | | 2012 Fluted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 26 | | 27 | | 28 | | 29 | | 30 | | 31 | | 32 | | |
| | CRS | F.S. | CRS | F.S. | CRS | F.S. | CRS | F.S. | CRS | F.S. | CRS | F.S. | CRS | F.S. | |
| 35-40 | 1816 | 2012 | 1816 | 2012 | 1816<br>1916 | 2012 | 1916<br>2016 | 2012 | 1916<br>2016 | 2012 | 2016 | 2012 | 2016<br>2018 | 2012 | |
| 40-45 | 1816 | 2012 | 1816<br>1916 | 2012 | 1916<br>2016 | 2012 | 1916<br>2016 | 2012 | 2016<br>2018 | 2012 | | | | | |
| 45-50 | 1816<br>1916 | 2012 | 1916<br>2016 | 2012 | 2016<br>2018<br>2114 | 2012 | 2016<br>2018<br>2114 | 2012 | | | | | | | |
| 50-55 | 1916<br>2016 | 2012 | 1916<br>2016 | 2012 | 2016<br>2018<br>2114 | 2012 | | | | | | | | | |
| 55-60 | 2016<br>2018 | 2012 | 2016<br>2018<br>2114 | 2012 | | | | | | | | | | | |
| 60-65 | 2016<br>2018 | 2012 | | | | | | | | | | | | | |
| 65-70 | [illegible] | | | | | | | | | | | | | | |
| 70-75 | | | | | | | | | | | | | | | |
| 75-80 | | | | | | | | | | | | | | | |
| 80-85 | | | | | | | | | | | | | | | |

There have been many discussions in the field and at the Archery Pro shops about Velocity, Trajectory, Penetration VS. Mass Weight. Some archers say you need the mass weight for penetration and other archers say you don't. With today's technology in arrow shaft design, you can achieve the same penetration with a certain increase in Velocity. With **X-CALIBER** fluted arrow shafts you also achieve a Flatter Trajectory, Better Accuracy and Greater Penetration because of the 40% decrease in actual outside surface area. See examples on Kinetic Energy chart. We at Advanced Archery Equipment hope you will enjoy these reference charts and thank you for your loyalty and continued interest in AAE Shafts & Accessories.

*Yours in Archery*

Carl Lekavich
President.

**ADVANCED ARCHERY EQUIPMENT**
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TELEPHONE: (213) 325-2772 (714) 660-0565 TELEX: 65-5441

# BOWHUNTING

## WITH EASTON ALUMINUM ARROW SHAFTS

# THE TECHNICAL SIDE-BEYOND THE BASICS OF HUNTING ARROW SELECTION

Arrow flight, speed, trajectory, accuracy, weight and penetration: these are the elements that determine success or failure in bow hunting. The more you understand about your equipment, the greater your chances of success in the field.

The performance of a hunting arrow with a sharp broadhead depends first upon the accuracy of the shot and, second, upon the energy of the arrow at impact. Skill and properly tuned equipment largely determine accuracy. Assuming reasonable accuracy, it is then the mass weight and speed at impact that determine the energy of the arrow and the effectiveness of the arrow on game. Easton Aluminum offers the widest range of arrow shaft sizes and weights available anywhere, thereby assuring the bowhunter that he will find in the Easton selection the ideal size and weight arrow for his draw length, his bow, his quarry, and the hunting conditions he faces.

The material which follows is an advanced guide for an individual's use in selecting the optimum bowhunting arrow. It presents factual data and figures with which the performance of different hunting arrow sizes can be compared and evaluated.

The following step-by-step procedure if used with the EASTON ALUMINUM HUNTING SHAFT SELECTION CHART, ARROW BALLISTIC CHARTS and the VELOCITY-ARROW DROP CHART will allow you to analyze the effect of hunting arrow weight and speed based upon a derived comparison figure called "Kinetic Energy". Kinetic Energy is the actual energy at impact (measured in foot-pounds) of a particular weight arrow traveling at a particular speed. For a hunting arrow, Kinetic Energy is not necessarily a measure of killing power. However, Kinetic Energy figures are a useful and logical means of comparing and evaluating the performance of different hunting arrow weights.

To determine the Kinetic Energy and impact velocity of your hunting arrow you will need to determine 1) your TOTAL ARROW WEIGHT and the 2) EXIT VELOCITY (speed as it leaves the bow) of your arrow using the following methods:

1) TOTAL ARROW WEIGHT can be determined by weighing on a grain scale or by referencing page 8 and 9 of the EASTON ALUMINUM HUNTING SHAFT SELECTION CHART. Immediately to the right of each arrow size on the chart is the weight of the arrow in grains. The listed arrow weight includes the weight of an aluminum R.P.S. insert *plus* 35 grains for the fletching and nock. Point or broadhead weight must be added to determine your TOTAL ARROW WEIGHT.

2) Arrow EXIT VELOCITY can be determined by shooting an arrow through a chronograph (check with your local archery dealer) or by using the "Arrow Drop" method described on page 12 and the accompanying VELOCITY-ARROW DROP CHART.

Once you have determined the EXIT VELOCITY of your arrow, then go to the ARROW BALLISTIC CHARTS and locate the chart that corresponds most closely to your TOTAL ARROW WEIGHT. In the left hand column (zero distance) on that chart find the closest listed EXIT VELOCITY to the EXIT VELOCITY of your arrow. The columns to the right of the EXIT VELOCITY column will show a Kinetic Energy and an impact velocity figure at various hunting distances. (Example: With a 600 grain arrow traveling at 200 feet per second upon release, the Kinetic Energy would be 51.4 foot pounds and 196.3 feet per second [fps] EXIT VELOCITY at 10 yards and 42.0 foot pounds and 177.6 fps EXIT VELOCITY at 60 yards).

Should you wish to be more precise in determining the Kinetic Energy and/or impact velocity of your arrow, you may use one of the following methods:

1) Interpolate between the figures on the TOTAL ARROW WEIGHT charts that bracket your TOTAL ARROW WEIGHT figure and between the EXIT VELOCITY figures that bracket your EXIT VELOCITY on those same two charts.

2) Use the formula shown below:

$$\text{Kinetic Energy} = \frac{(\text{Impact Velocity})^2 \times \text{Arrow Mass Weight}}{2}$$

Exact impact velocity can be determined by shooting through a chronograph at various distances. You cannot use EXIT VELOCITY in this formula.

The mass weight of an arrow in pounds is calculated by dividing the TOTAL ARROW WEIGHT of the arrow (in grains) by 7000 x 32.16.

Kinetic Energy is measured in foot pounds at point of impact. The formula can be written as:

$$\begin{array}{l}\text{Kinetic}\\ \text{Energy}\\ \text{At Impact}\end{array} = \frac{\text{Impact Velocity} \times \text{Impact Velocity} \times \text{Grain Weight Of Arrow}}{2 \times 7000 \times 32.16}$$

As you delve more deeply into the technical process of arrow selection, one other vital element must be considered. That element is the anticipated hunting situation. The real key to selecting the optimum bowhunting arrow is to carefully combine the calculated comparison figures with the specific nature of the expected hunting situation. Factors such as the distance of the average shot, the terrain, and the size of the game must be balanced with the technical factors of arrow speed, arrow weight and resultant Kinetic Energy. Specific bowhunting conditions will often call for a different weight arrow. For example, the ideal arrow for a 15 yard tree stand shot at whitetail buck may not be the ideal arrow for a 50 yard stalking shot in open country at pronghorn antelope. Larger game at a reliably known and reasonably short distance may demand an arrow possessing maximum weight and Kinetic Energy. Speed and flatter trajectory would therefore become secondary considerations. On the other hand, a longer shot at an antelope might require an arrow with higher speed and therefore a flat trajectory. The resultant loss of Kinetic Energy is traded by the hunter for increased accuracy at long and/or unknown distances.

Knowing your equipment well and then selecting a hunting arrow weight based on desired arrow performance for a specific hunting condition is the formula for success.

The best bowhunters have looked to Easton Aluminum since 1946 for technical information and the widest choice of high performance hunting shafts available.

# ARROW DROP METHOD OF DETERMINING ARROW EXIT VELOCITY

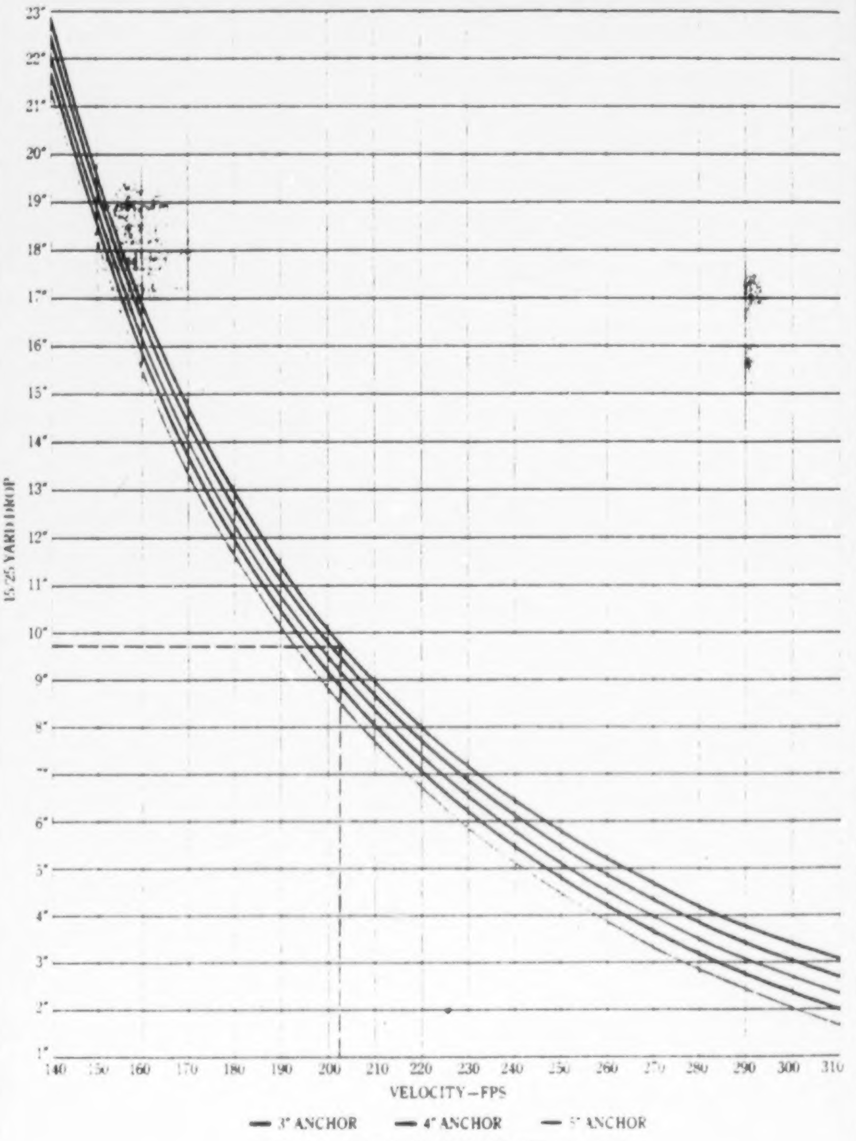
To find EXIT VELOCITY by the Arrow Drop method, begin by measuring your anchor point height (the distance between the center of your eye and the top of the arrow shaft) while at full draw using your normal anchor point. Next, mark off two lines exactly 15 and 25 yards from a target on level ground and place an aiming spot on the target. With repeated shooting from the 15 yard line, carefully set a sight pin so your arrows group closely around the aiming spot. A wooden match taped to the bow can act as a sight pin if you do not use a sight. Then move back to the 25 yard mark and shoot again using the same 15 yard sight pin setting while aiming at the same spot on the target. When you have established a good arrow group below the aiming spot, measure how much lower the center of your 25 yard group is below the center of the aiming spot. This measurement is your Arrow Drop figure. With your Arrow Drop figure then go to the VELOCITY-ARROW DROP CHART and from the Arrow Drop figure listed on the vertical axis, move horizontally across the chart until you reach a curve or a point between the curves corresponding to your measured anchor point height. Then move straight down from that intersection or point to locate the arrow EXIT VELOCITY on the horizontal axis of the chart.

Example: With a drop of 9.6 inches and a three inch anchor point height, the EXIT VELOCITY is 203 feet per second.

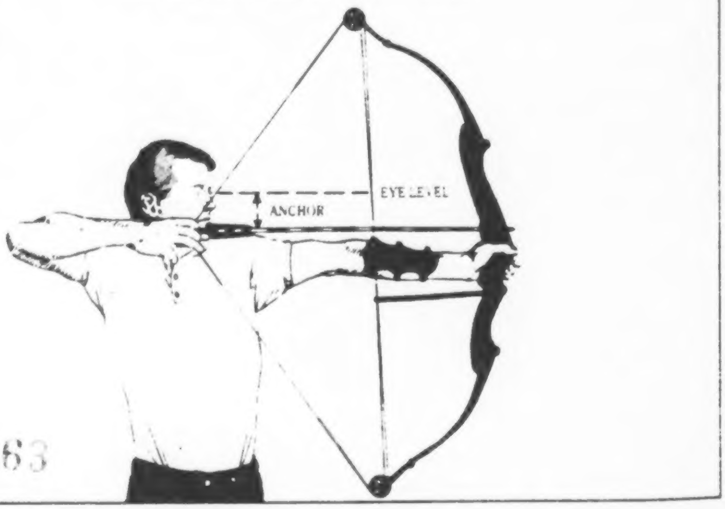
*Easton is grateful to Larry Luterman for the many hours he worked creating the technical ballistic information presented in this catalog.*

*Edited by Elizabeth White.*

VELOCITY VS ARROW DROP AT 25 YARDS WITH 15 YARD MARK



BALLISTIC COEFFICIENT = 6 x 10⁻⁴



# ARROW BALLISTIC CHARTS

### 280 grains

| | Exit Velocity | Distance in Yards | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 |
| Velocity | 200 | 196.3 | 192.5 | 188.3 | 185.0 | 181.3 | 177.6 |
| Energy | | 24.0 | 23.0 | 22.2 | 21.3 | 20.4 | 19.6 |
| Velocity | 220 | 215.9 | 211.8 | 207.7 | 203.6 | 199.4 | 195.3 |
| Energy | | 29.0 | 27.9 | 26.8 | 25.8 | 24.7 | 23.7 |
| Velocity | 240 | 235.5 | 231.0 | 226.5 | 222.1 | 217.6 | 213.1 |
| Energy | | 34.5 | 33.2 | 31.9 | 30.7 | 29.4 | 28.2 |
| Velocity | 260 | 255.1 | 250.3 | 245.4 | 240.6 | 235.7 | 230.8 |
| Energy | | 40.5 | 39.0 | 37.5 | 36.0 | 34.5 | 33.1 |
| Velocity | 280 | 274.8 | 269.5 | 264.3 | 259.1 | 253.8 | 248.6 |
| Energy | | 47.0 | 45.2 | 43.4 | 41.7 | 40.1 | 38.4 |
| Velocity | 300 | 294.4 | 288.8 | 283.2 | 277.6 | 272.0 | 266.4 |
| Energy | | 53.9 | 51.9 | 49.9 | 47.9 | 46.0 | 44.1 |

### 300 grains

| | Exit Velocity | Distance in Yards | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 |
| Velocity | 200 | 196.3 | 192.5 | 188.8 | 185.0 | 181.3 | 177.6 |
| Energy | | 25.7 | 24.7 | 23.8 | 22.8 | 21.9 | 21.0 |
| Velocity | 220 | 215.9 | 211.8 | 207.7 | 203.6 | 199.4 | 195.3 |
| Energy | | 31.1 | 29.9 | 28.7 | 27.6 | 26.5 | 25.4 |
| Velocity | 240 | 235.5 | 231.0 | 226.5 | 222.1 | 217.6 | 213.1 |
| Energy | | 37.0 | 35.6 | 34.2 | 32.9 | 31.5 | 30.3 |
| Velocity | 260 | 255.1 | 250.3 | 245.4 | 240.6 | 235.7 | 230.8 |
| Energy | | 43.4 | 41.7 | 40.1 | 38.6 | 37.0 | 35.5 |
| Velocity | 280 | 274.8 | 269.5 | 264.3 | 259.1 | 253.8 | 248.6 |
| Energy | | 50.3 | 48.4 | 46.5 | 44.7 | 42.9 | 41.2 |
| Velocity | 300 | 294.4 | 288.8 | 283.2 | 277.6 | 272.0 | 266.4 |
| Energy | | 57.8 | 55.6 | 53.4 | 51.3 | 49.3 | 47.3 |

### 320 grains

| | Exit Velocity | Distance in Yards | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 |
| Velocity | 200 | 196.3 | 192.5 | 188.8 | 185.0 | 181.3 | 177.6 |
| Energy | | 27.4 | 26.3 | 25.3 | 24.3 | 23.4 | 22.4 |
| Velocity | 220 | 215.9 | 211.8 | 207.7 | 203.6 | 199.4 | 195.3 |
| Energy | | 33.1 | 31.9 | 30.7 | 29.5 | 28.3 | 27.1 |
| Velocity | 240 | 235.5 | 231.0 | 226.5 | 222.1 | 217.6 | 213.1 |
| Energy | | 39.4 | 37.9 | 36.5 | 35.1 | 33.7 | 32.3 |
| Velocity | 260 | 255.1 | 250.3 | 245.4 | 240.6 | 235.7 | 230.8 |
| Energy | | 46.3 | 44.5 | 42.8 | 41.1 | 39.5 | 37.9 |
| Velocity | 280 | 274.8 | 269.5 | 264.3 | 259.1 | 253.8 | 248.6 |
| Energy | | 53.7 | 51.6 | 49.6 | 47.7 | 45.8 | 43.9 |
| Velocity | 300 | 294.4 | 288.8 | 283.2 | 277.6 | 272.0 | 266.4 |
| Energy | | 61.6 | 59.3 | 57.0 | 54.8 | 52.6 | 50.4 |

### 340 grains

| | Exit Velocity | Distance in Yards | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 |
| Velocity | 200 | 196.3 | 192.5 | 188.8 | 185.0 | 181.3 | 177.6 |
| Energy | | 29.1 | 28.0 | 26.9 | 25.8 | 24.8 | 23.8 |
| Velocity | 220 | 215.9 | 211.8 | 207.7 | 203.6 | 199.4 | 195.3 |
| Energy | | 35.2 | 33.9 | 32.6 | 31.3 | 30.0 | 28.8 |
| Velocity | 240 | 235.5 | 231.0 | 226.5 | 222.1 | 217.6 | 213.1 |
| Energy | | 41.9 | 40.3 | 38.7 | 37.3 | 35.8 | 34.3 |
| Velocity | 260 | 255.1 | 250.3 | 245.4 | 240.6 | 235.7 | 230.8 |
| Energy | | 49.1 | 47.3 | 45.5 | 43.7 | 42.0 | 40.2 |
| Velocity | 280 | 274.8 | 269.5 | 264.3 | 259.1 | 253.8 | 248.6 |
| Energy | | 57.0 | 54.8 | 52.8 | 50.7 | 48.6 | 46.7 |
| Velocity | 300 | 294.4 | 288.8 | 283.2 | 277.6 | 272.0 | 266.4 |
| Energy | | 65.5 | 63.0 | 60.6 | 58.8 | 55.9 | 53.6 |

### 360 grains

| | Exit Velocity | Distance in Yards | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 |
| Velocity | 190 | 186.4 | 182.9 | 179.3 | 175.8 | 172.2 | 168.7 |
| Energy | | 27.8 | 26.7 | 25.7 | 24.7 | 23.7 | 22.8 |
| Velocity | 210 | 206.1 | 202.1 | 198.2 | 194.3 | 190.4 | 186.4 |
| Energy | | 34.0 | 32.7 | 31.4 | 30.2 | 29.0 | 27.8 |
| Velocity | 230 | 225.7 | 221.4 | 217.1 | 212.8 | 208.5 | 204.2 |
| Energy | | 40.7 | 39.2 | 37.7 | 36.2 | 34.8 | 33.3 |
| Velocity | 250 | 245.3 | 240.7 | 236.0 | 231.3 | 226.6 | 222.0 |
| Energy | | 48.1 | 46.3 | 44.5 | 42.8 | 41.1 | 39.4 |
| Velocity | 270 | 265.0 | 259.9 | 254.9 | 249.8 | 244.8 | 239.7 |
| Energy | | 56.2 | 54.0 | 52.0 | 49.9 | 47.9 | 45.9 |
| Velocity | 290 | 284.6 | 279.2 | 273.7 | 268.3 | 262.9 | 257.5 |
| Energy | | 64.8 | 62.3 | 59.9 | 57.6 | 55.3 | 53.0 |

### 380 grains

| | Exit Velocity | Distance in Yards | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 |
| Velocity | 190 | 186.4 | 182.9 | 179.3 | 175.8 | 172.2 | 168.7 |
| Energy | | 29.3 | 28.2 | 27.1 | 26.1 | 25.0 | 24.0 |
| Velocity | 210 | 206.1 | 202.1 | 198.2 | 194.3 | 190.4 | 186.4 |
| Energy | | 35.9 | 34.5 | 33.2 | 31.9 | 30.6 | 29.3 |
| Velocity | 230 | 225.7 | 221.4 | 217.1 | 212.8 | 208.5 | 204.2 |
| Energy | | 43.0 | 41.4 | 39.8 | 38.2 | 36.7 | 35.2 |
| Velocity | 250 | 245.3 | 240.7 | 236.0 | 231.3 | 226.6 | 222.0 |
| Energy | | 50.8 | 48.9 | 47.0 | 45.2 | 43.3 | 41.6 |
| Velocity | 270 | 265.0 | 259.9 | 254.9 | 249.8 | 244.8 | 239.7 |
| Energy | | 59.3 | 57.0 | 54.8 | 52.7 | 50.6 | 48.5 |
| Velocity | 290 | 284.6 | 279.2 | 273.7 | 268.3 | 262.9 | 257.5 |
| Energy | | 68.4 | 65.8 | 63.2 | 60.8 | 58.3 | 56.0 |

### 400 grains

| | Exit Velocity | Distance in Yards | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 |
| Velocity | 190 | 186.4 | 182.9 | 179.3 | 175.8 | 172.2 | 168.7 |
| Energy | | 30.9 | 29.7 | 28.6 | 27.5 | 26.3 | 25.3 |
| Velocity | 210 | 206.1 | 202.1 | 198.2 | 194.3 | 190.4 | 186.4 |
| Energy | | 37.7 | 36.3 | 34.9 | 33.5 | 32.2 | 30.9 |
| Velocity | 230 | 225.7 | 221.4 | 217.1 | 212.8 | 208.5 | 204.2 |
| Energy | | 45.3 | 43.5 | 41.9 | 40.2 | 38.6 | 37.0 |
| Velocity | 250 | 245.3 | 240.7 | 236.0 | 231.3 | 226.6 | 222.0 |
| Energy | | 53.5 | 51.5 | 49.5 | 47.5 | 45.6 | 43.8 |
| Velocity | 270 | 265.0 | 259.9 | 254.9 | 249.8 | 244.8 | 239.7 |
| Energy | | 62.4 | 60.0 | 57.7 | 55.4 | 53.2 | 51.0 |
| Velocity | 290 | 284.6 | 279.2 | 273.7 | 268.3 | 262.9 | 257.5 |
| Energy | | 72.0 | 69.3 | 66.6 | 64.0 | 61.4 | 58.9 |

### 420 grains

| | Exit Velocity | Distance in Yards | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 |
| Velocity | 190 | 186.4 | 182.9 | 179.3 | 175.8 | 172.2 | 168.7 |
| Energy | | 32.4 | 31.2 | 30.0 | 28.8 | 27.7 | 26.5 |
| Velocity | 210 | 206.1 | 202.1 | 198.2 | 194.3 | 190.4 | 186.4 |
| Energy | | 39.6 | 38.1 | 36.6 | 35.2 | 33.8 | 32.4 |
| Velocity | 230 | 225.7 | 221.4 | 217.1 | 212.8 | 208.5 | 204.2 |
| Energy | | 47.5 | 45.7 | 44.0 | 42.2 | 40.6 | 38.9 |
| Velocity | 250 | 245.3 | 240.7 | 236.0 | 231.3 | 226.6 | 222.0 |
| Energy | | 56.1 | 54.0 | 52.0 | 49.9 | 47.9 | 46.0 |
| Velocity | 270 | 265.0 | 259.9 | 254.9 | 249.8 | 244.8 | 239.7 |
| Energy | | 65.5 | 63.0 | 60.6 | 58.2 | 55.9 | 53.6 |
| Velocity | 290 | 284.6 | 279.2 | 273.7 | 268.3 | 262.9 | 257.5 |
| Energy | | 75.6 | 72.7 | 69.9 | 67.2 | 64.5 | 61.9 |

*Tables are based on a ballistic coefficient of* $6x10^{-4}$ *which is appropriate for most hunting arrows with plastic vanes.*

Return RH.

HUNTERS RESPECT WILDLIFE
FRED BEAR SPORTS CLUB

# The Big Sky

Vol. 11, No. 4 Gainesville, Florida 32601 Summer 1983

# AN ARCHERY EQUIPMENT PERSPECTIVE

## NON-GAME TAX CHECKOFF

This year, Indiana residents will be able to contribute a portion of their 1982 income tax refund to their state's Department of Natural Resources, Division of Fish and Game.

The Indiana Wildlife Federation played an instrumental role in securing passage of the new non-game check-off, approved by the 1981-82 Indiana General Assembly.

Officials expect $300,000 or more will be raised during the first year the check-off is in effect.

Nationally, $3.3 million was raised last year through the income tax check-off program, now underway in over 20 states. Contributions averaged $5.73 each, based on the 570,000-plus taxpayers participating in 1982.

*National Wildlife Federation*

## SEND US YOUR HUNTING PHOTOS

FBSC members are invited to send in their recent photographs of animals that have been harvested with bow and arrow. Be sure to scotchtape a piece of paper to the back of each print with your name, address, telephone, year the animal was taken, make of bow, arrows and hunting head used. Also the species, and area taken in. Be sure to include your FBSC number. Send them to: Dick Lattimer, Fred Bear Sports Club, Fred Bear Drive at Archer Road, Gainesville, Florida 32601.

BOWHUNTING SPOKEN HERE
Enjoy a new hunting thrill . . . go BOWHUNTING

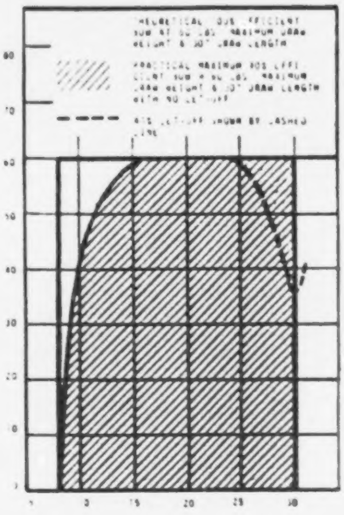


FIGURE 1. Typical force-draw diagrams for: Theoretical 100% efficient bow & practical maximum 90% efficient bow.

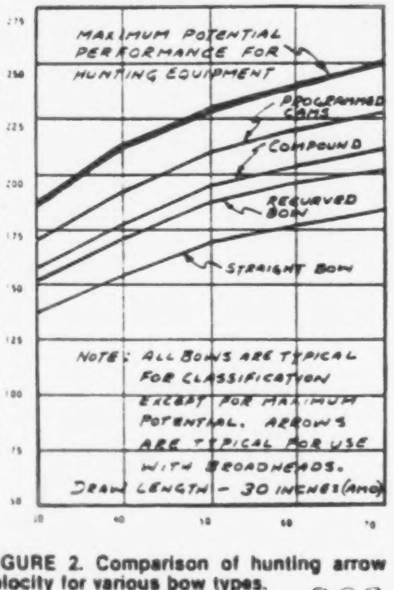


FIGURE 2. Comparison of hunting arrow velocity for various bow types.

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By
*Norbert F. Mullaney*
Professional Engineer
Independent Testing Laboratory
Milwaukee, Wisconsin

*(Editor's Note: With all of the technological advances in archery equipment in recent years, the bow and arrow still remains a viable historical "primitive" weapon. Its use as a recreational tool has never been more popular or valid as it is today. Norb Mullaney's fresh viewpoint on this subject points this out.)*

It began when archers first taped a matchstick or a hatpin to the back of the bow riser and used it for a sighting device. It became more audible when aluminum alloy arrows demonstrated consistent superiority over traditional wooden arrows. It was rekindled when release aids began to be used by more than just a handful of experimenters and flight shooters. But, it has become a matter for serious consideration since the introduction and refinement of the compound bow.

More frequently now, since the appearance of programmed cams for compound bows, we hear concern voiced over the continued improvement of archery equipment as a result of seemingly never ending technological development. Serious, knowledgeable, and thinking archery people as well as many state DNR and Fish and Game authorities wonder whether our "primitive" long bow and arrow is becoming a space-age projectile launcher that will ultimately rival a firearm in hunting efficiency and effect.

Quite frankly, this concern is not founded in fact. *It can be readily demonstrated that the generic "long bow" has distinct physical and practical limitations that no amount of advanced science or technology can surmount.* Some small improvements are possible over the up-to-date bows and arrows that we know and use today,

*Continued on Page 2*

*Continued from Page 1*

however, none of these potential improvements can achieve any highly significant increase in performance or accuracy over present equipment. Here is why:

The generic term "long bow" refers to a hand-drawn, hand-held, and hand-released arrow launching device whether it be a long straight-limbed bow, recurve, or compound. "Hand-released" includes the use of hand-held release aids.

As long as the bow is hand-held and hand-drawn, the energy or work that is stored and then released to launch the arrow is limited to that which a particular human being can muster within the capability of his or her arm and back muscles and the length of arms and shoulder expanse. While a few heavy-bow advocates espouse bows with draw weights of ninety pounds or more most hunting bows fall in the seventy-pounds-or-less classification. Recently obtained data shows that the average hunting bow draw weight is reasonably close to sixty pounds. Since most serious hunting archers are inclined to use the maximum draw weight bow that they can handle with consistent accuracy, this figure of sixty pounds draw weight can be used as a practical average peak weight for this presentation. Experience over the last forty years has shown that it is not likely to change very much as a result of muscle culture. From the standpoint of technology, peak weight is peak weight, no matter what the design of the launching device, since it is required to be hand-drawn and hand-held.

The only other dimension that defines the stored energy is draw length. The popularity of compound bows has increased the average draw length to about thirty inches, but only about twenty to twenty-two inches of this is actual power stroke. The remainder is the brace height of the bow.

Combining the peak draw weight and power stroke yields the total maximum energy that can be achieved with the typical hunting bow provided that it is 100 percent efficient in storing energy. This combination is shown graphically in Figure 1. The maximum potential energy that could possibly be generated within these practical average limitations of human strength and physical structure is shown by the shaded area. It amounts to 110 foot-pounds for a 60 pound draw weight.

However, *it is not practical or even physically possible to achieve 100 percent efficiency in energy storage.* Even if it were, such a bow would be unbelievably harsh and hardly conducive to any degree of accuracy. With the use of programmed cams and considering a let-off of 45 to 50 percent, *the best of today's bows achieve an energy storage efficiency of about 85 percent.* Without let-off, this can be increased to about 90 percent. This means that the typical 60 pound hunting bow might ultimately be pushed to store about 99 foot pounds of energy. Typical force-draw curves for such an ideal bow are also shown in Figure 1.

At the present time, we feel certain that such a bow would be difficult to shoot at best, but we can say without question that it would require a good deal of physical conditioning for an archer to handle and control this type of equipment.

Just because we could store nearly 100 foot pounds of energy in a typical hunting bow doesn't mean that we can transfer all of this potential energy to the arrow that we wish to launch. *It is a basic concept of physics that no mechanism is 100 percent dynamically efficient. To date, no bow has realized a dynamic efficiency greater than about 84 percent.* The dynamic efficiency is a measure of just how much of the stored energy in the bow is transferred to the arrow during launch.

Dynamic efficiency is made up of several factors which include not only the design and functional efficiency of the bow, but also the interaction between the bow and the arrow. In addition, the reaction of the arrow structure itself is also involved. Recent experimental work with bows using programmed cams has demonstrated that bows that store large amounts of energy for a given draw weight require heavier and stiffer arrows when compared to other types of bows of similar draw weight. Despite the added stiffness, the arrows flex more upon release, increasing reaction forces and resulting in a net loss of dynamic efficiency ranging from 3 to 10 percent.

In other words, it is possible to store more energy in a bow, but when it comes to transferring that energy to an arrow, *we have reached the point of diminishing returns.*

The need for a heavier, stiffer arrow also has a detrimental effect on arrow velocity. The heavier arrow requires more energy to launch at the same velocity as a lighter arrow. Therefore, potentially more powerful bows which must use heavier arrows, gain arrow velocity at a diminishing rate. Granted there is more kinetic energy in the arrow, but the gain in arrow velocity is disproportionately less.

To better visualize these effects, refer to Figure 2. This chart compresses about fifty years of technological development of archery equipment into four curves. It shows the progression of performance of hunting equipment from the straight bow through the latest development of programmed cams for compound bows. But, it also does much more. It shows the practical maximum performance potential for the hunting bow and arrow combination based on average human physique and the accepted definition of "hand-drawn, hand-held, and hand-released."

Commercial equipment may never attain this maximum level, but *we can be assured that it will not exceed it and still remain within the established definition of "long bow."*

It has required almost fifty years to gain 35 to 45 feet per second increase in the velocity of a typical hunting arrow. Most of this gain has been achieved in the past fifteen years, which tends to dramatize the change. There are perhaps an additional 20 to 25 feet per second that can be achieved before the maximum potential is fully exploited. When and if this happens, we will still have a low velocity, high-arch trajectory, projectile system that will be critical for elevation and external influences. External influences include such things as wind and obstacles, even though the latter are as minor as a leaf or twig.

In addition, the internal ballistics of the bow and arrow (what happens from the time of release until the arrow clears the bow) are delicately balanced for proper launch and flight. A small error in the shooter's form or a momentary lapse in concentration can result in an errant arrow. It is far more complex than just aiming and squeezing off. In a firearm, the design of the system establishes and rigidly controls the internal ballistics. With a bow and arrow, each individual archer greatly influences the internal ballistics, and this individual influence will frequently vary from shot to shot.

Even the use of sophisticated sight equipment has an element of uncertainty. Because of the high-arch trajectory of the arrow, distance to the target must be estimated quite accurately especially beyond twenty yards. As the distance to the target increases, the potential for error from this source alone becomes greater. The instinctive or bare-bow archer operates under a substantially greater handicap.

*Continued on Page 3*

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Production: Pat Wiseman
Staff: Charlie Kroll

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*Continued from Page 2*

He or she relies on a visual distance judgment plus an intimate knowledge of the normal trajectory of his arrow to direct the shot. This system introduces critical variables that only skill and regular practice can conquer on a consistent basis.

To establish a perspective for the high-arch trajectory of an arrow, consider that a 540 grain typical hunting arrow with an initial horizontal velocity of 200 feet per second will drop about 9½ feet in 50 yards. A 170 grain type 30-30 projectile from a standard load rifle cartridge will have a muzzle velocity about 2200 feet per second, and drop less than 1½ inches for the same range. (Fig. 3).

*Taken at its maximum potential, the bow and arrow remains a minimum velocity, multiple-variable, short-range hunting system.* With practical hunting equipment, it will never reach one-quarter the speed of sound. The individual human control of the internal ballistics phase of the launch can and will continue to limit accuracy for the great majority of bowhunters. This factor is even more critical with equipment that will deliver arrow velocity in the higher levels. In other words, control is more important and also more difficult to achieve with equipment capable of providing the higher velocity arrows.

These factors combine to keep the up-to-the-minute hand-drawn, hand-held, and hand-released long bow and arrow a "primitive" hunting system. *Within this accepted definition, there is insufficient scientific potential to progress beyond that category.*

# BEAR ARCHERY ACQUIRES JENNINGS® COMPOUND BOWS

GAINESVILLE, FLORIDA—Robert F. Kelly, president, Bear Archery subsidiary of Kidde, Inc., today announced the acquisition by Bear of the Jennings Compound Bow line.

The Jennings® line of bows to be made by Bear Archery, will continue the philosophy, high quality design, construction and performance of Jennings® bows to which the archery world has become accustomed.

Kelly stated, "We are delighted to bring together two of the finest names in the Archery Industry today. I am pleased to announce that Tom Jennings will continue his association with Jennings® as a consultant to Bear Archery. Tom's innovative mind and product developments have played a major role in the popularity and growth of the sports of target archery and bowhunting over the past two decades.

"Bear and the Jennings® Company shared many of the same dealers and we know that they too will be pleased with the continuation of the Jennings® product line and bowmaking philosophy.

"We expect to begin delivery of the Jennings® line from our Gainesville location within 120 days."

Company spokesman indicated that warranty service on Jennings® bows made by Bear will be taken care of promptly.

For more information about Jennings Compound Bows, call Area Code 904-376-0476, or write: Jennings, Post Office Box 1750, Gainesville, FL 32601.

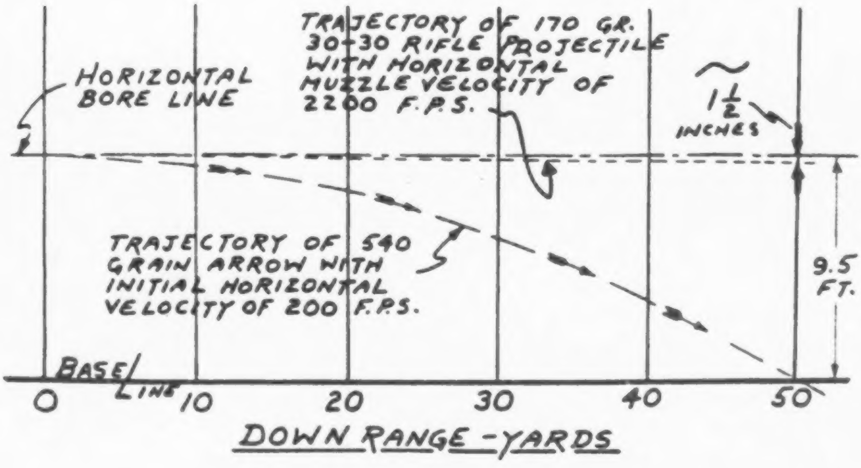


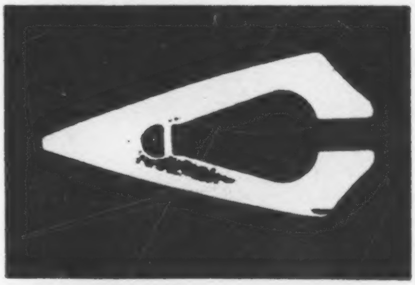
FIGURE 3. Comparison of projecticle drop at 50 yards.

# NEW MODIFICATION PERFECTS BEAR'S SUPER RAZORHEAD

Gainesville, Florida...In 1977 when the new Bear Super Razorhead S/S was introduced, a simplified system of attaching the machined aluminum alloy ferrule to the stainless steel blade was inaugurated.

On the old-style Razorheads the ferrule and blade had been joined by spot welding. In the new version, a high pressure clamping action took the place of the weld.

Bowhunters hailed the upgraded stainless steel heads for their ability to withstand rust and corrosion and the resistance of the highly sharpened blade edges to dulling.



One difficulty did, however, occasionally surface in the field. Upon hitting rocks, tree trunks or other hard surfaces at an angle, the fore end of the ferrule sometimes separated from its pressure juncture with the blade.

Now, thanks to a new D-Hole Modification worked out by Bear's Research & Development Department, the juncture between blade and ferrule has been strengthened to the point where it will withstand 300 lbs. of blow force. Not only is the D-Hole Modification many times stronger, but the blade seating remains undeviating through lack of any clamping pressure distortion and the alignment of blade and ferrule is consistently truer.

Confirming proof of the strength inherent in this new D-Hole Modification can be had by clamping the fore end of the head in a vise and working it back and forth through 180 degrees until the blade snaps off. It will be found that the ferrule remains firmly attached to the blade throughout this 'torture' test.

Since it was first introduced by Fred Bear back in 1956, the Bear Razorhead has been the favorite of knowledgeable bowhunters, having probably accounted for more than half of the big game animals taken by bowmen since that time. Now, with this latest modification, we at Bear can state unequivocably that it is the finest broadhead in the world.

*Charlie Kroll*

**SUPPLEMENT TO:**

# NRA hunter safety and conservation program

## INSTRUCTOR'S MANUAL

Chapter S-1

### BOWHUNTING

TEACHING LESSON PLAN
INSTRUCTIONAL UNIT
TRAINING SUPPLEMENT

---

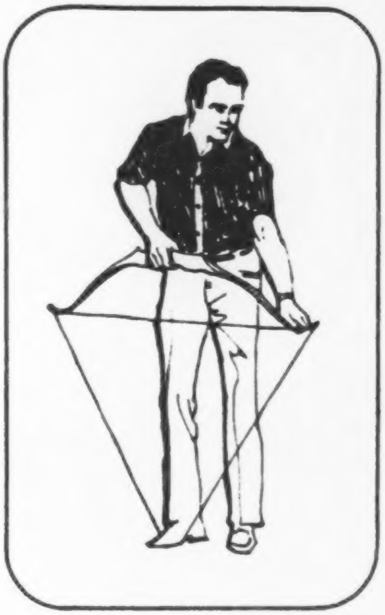
## TEACHING LESSON PLAN — Bowhunting

| | |
|---|---|
| OBJECTIVE: | To have a basic knowledge of archery equipment, its care and safe handling. To understand the fundamentals of shooting and their relationship to field situations. To know and understand the limitations of archery equipment. To accept the personal limitations of the bowhunter. |
| METHOD OF TEACHING: | Lecture; demonstration; practical exercises, if possible. |
| TIME REQUIRED: | One hour. Practical work, including both stringing the bow and shooting, will require additional time. The amount of time will be determined by the number of qualified assistants, the amount of equipment, and the number of target positions available. |
| ASSISTANTS REQUIRED: | One demonstrator. |
| INSTRUCTIONAL AIDS: | Student handbook, charts, slides or actual photographs; selection of archery equipment. |
| PHYSICAL SET-UP: | Classroom with demonstration area situated so all can see. |

BEST COPY AVAILABLE

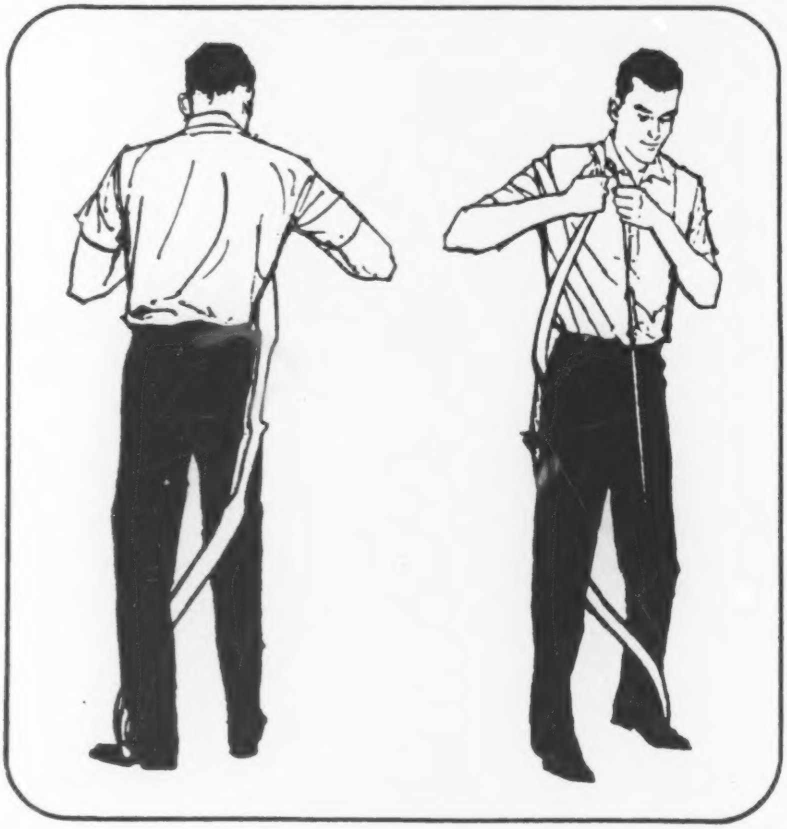
## III. Classroom Exercises—Bracing the Bow

### A. Cord stringer method:



1. Slip the upper loop over the upper bow limb.
2. Place the lower bowstring loop in the groove of the lower nock, and secure with a rubber bow-tip protector.
3. Fit the stringer pouches over the bow tips.
4. Stand on the center of the bowstringer, pulling the bow up while holding it by the handle.
5. When the bow has sufficient flex, slip the upper string loop into the grooved nock.

### B. Step-through method:

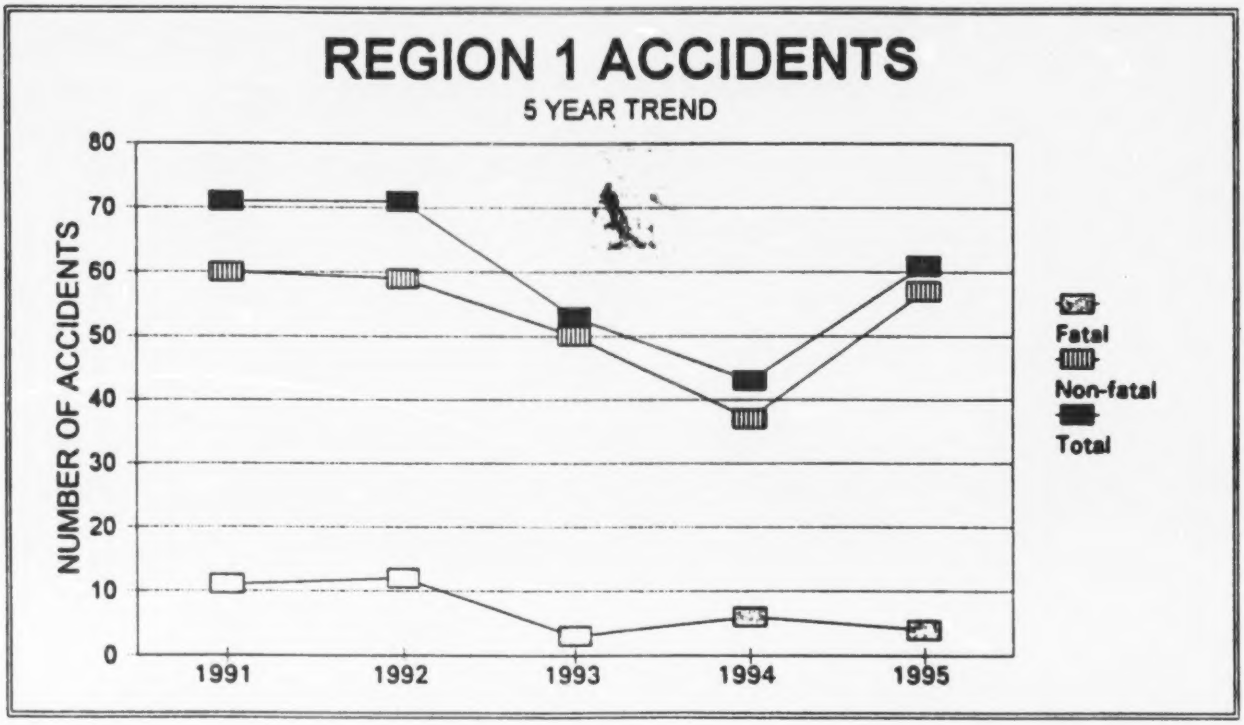


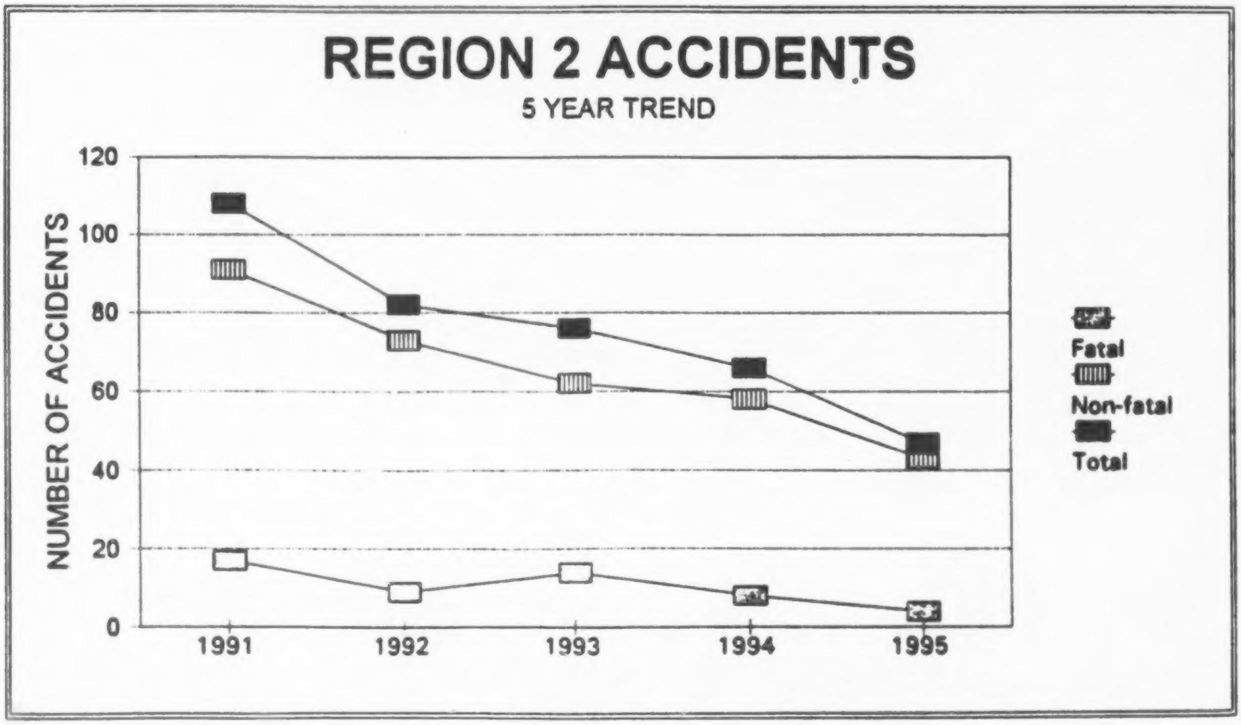
1. The bowstring should be looped over the upper limb and nocked on the lower limb, as described in the previous method.
2. With the right leg, step through or between string and bow, and hook lower recurve on the outside of left foot and over the instep. The use of a foot or ankle harness will guard against twisting the bow limb.
3. Place thigh against the bow handle and apply pressure backward, at the same time bending the bow by leaning forward from the waist and applying pressure with the right hand. The string loop can then be slipped into place in the upper nock. Before pressure is released, check to make sure the string loops are firmly seated in the bow nocks.

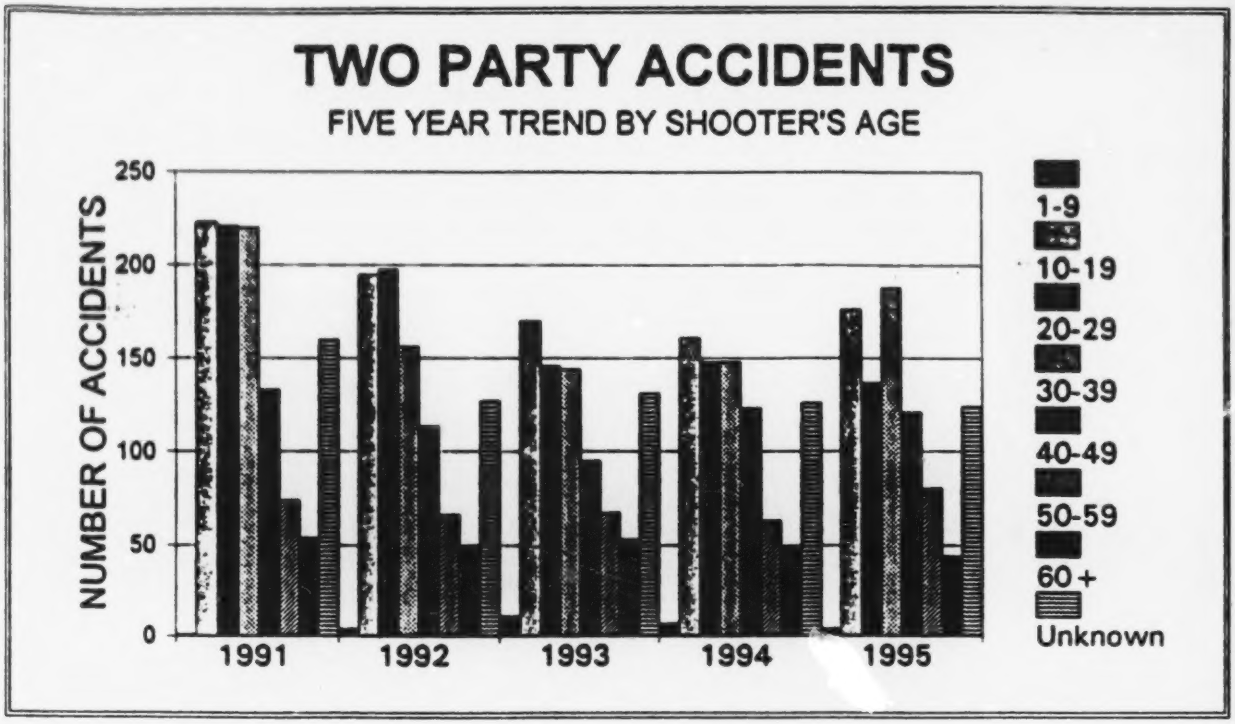
# INTERNATIONAL HUNTER EDUCATION ASSOCIATION

# 1995 Hunting Accident Report

## Hunting Accident Report with Graphics of 1991-1995 Data

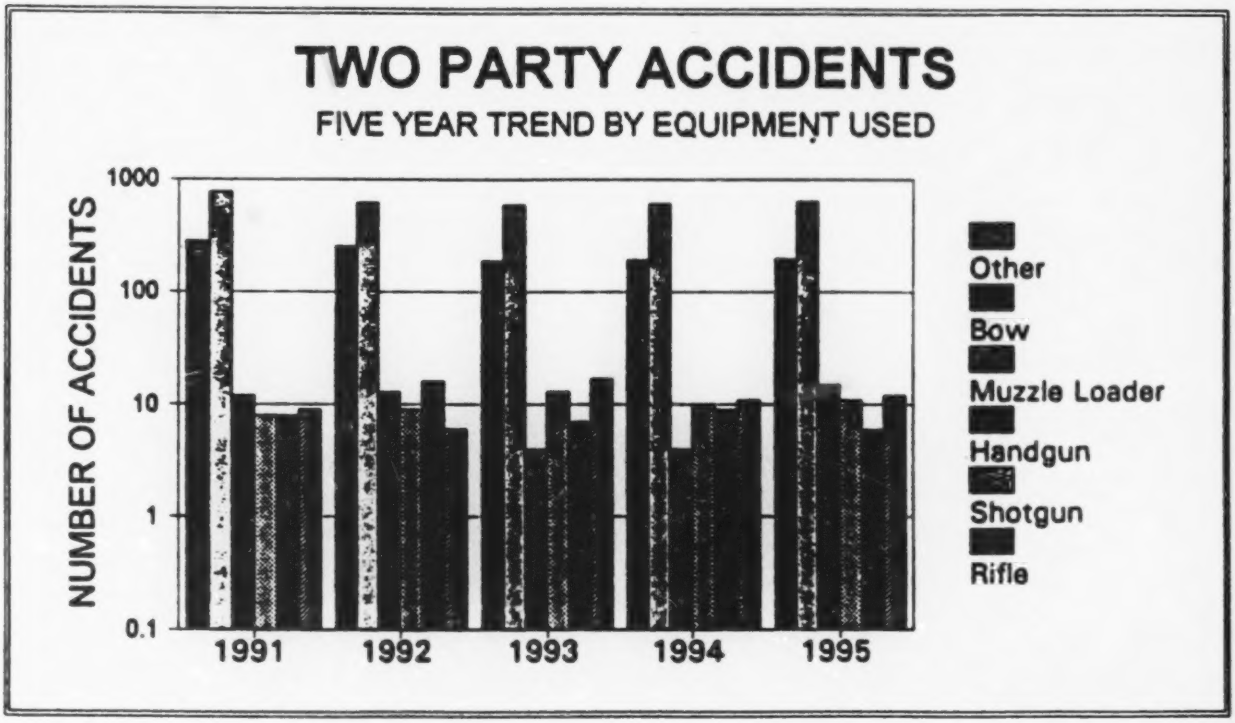

REGION 1 ACCIDENTS
5 YEAR TREND


REGION 2 ACCIDENTS
5 YEAR TREND



TWO PARTY ACCIDENTS

FIVE YEAR TREND BY SHOOTER'S AGE

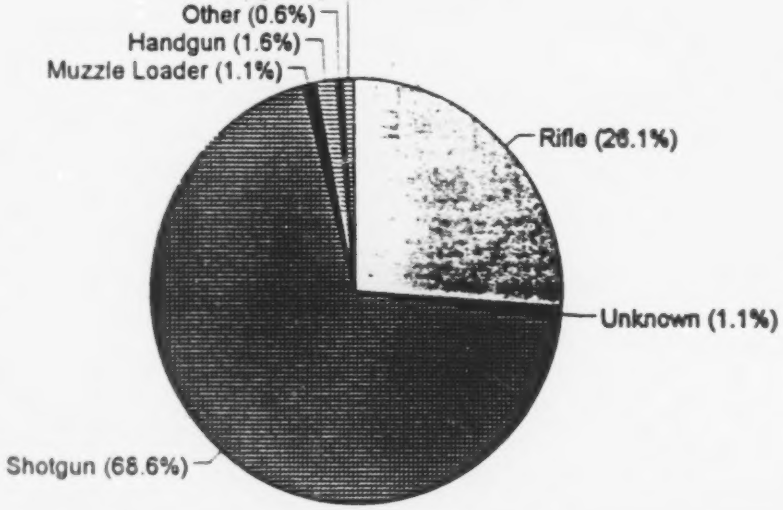


TWO PARTY ACCIDENTS

FIVE YEAR TREND BY EQUIPMENT USED

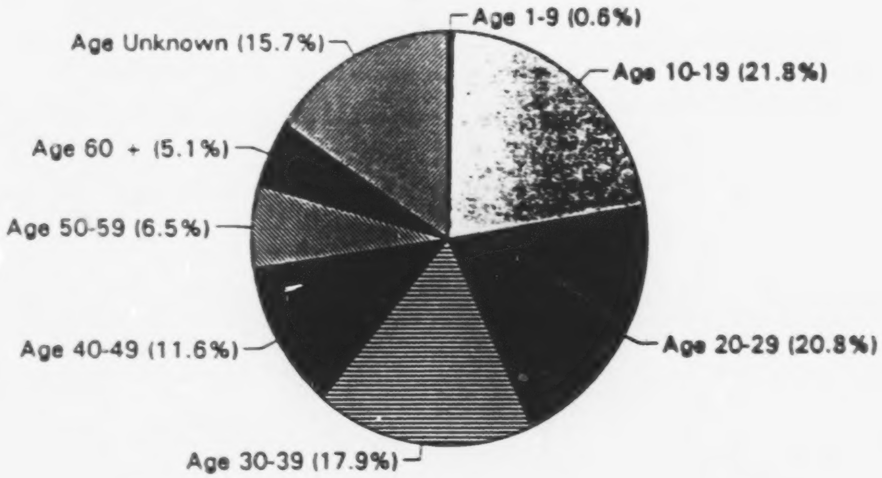
# 1986-1995 TWO PARTY ACCIDENTS

## BY EQUIPMENT BEING USED



# 1986-1995 TWO PARTY ACCIDENTS

## BY AGE OF SHOOTER



**Vickie Smith**
**Composite Science**
**Fulmore Middle School, Austin ISD**

**Texas Parks & Wildlife**
**Project WILD, Austin**
**Kathryn Hampton, Mentor**

# TTIP
# Curriculum Implementation Plan
# Abstract

Name: Vickie Dunlevy Smith

Internship: Texas Parks and Wildlife Department

School: Fulmore Middle School, Austin, Texas

Subject: Life Science

Activities:
Measuring urban mammal skulls
Learning Scientific names for skull parts
Using a key to identify urban mammal skulls
cleaning mammal skulls

Summary:

Life Science involves the study of living organisms. With the use of teeth, jaws, and skulls students can examine what was once alive and see how each mammal species has adapted to their environment. The objective of the Key to Urban Mammals exercise is for the students to master using a scientific tool- the key-, applying a specific vocabulary, practice with measurement, and using observation skills to help determine more about the urban mammals and their habitat.

The Key to Urban Mammals is one of many activities that can be found in a special educational trunk available through urban biologist with Texas Parks and Wildlife Department. The WILD in the City trunk contains 12 mammal skulls, 9 samples of fur, 7 books, 14 slides of the urban mammals, track and scat replicas, deer antlers, a cow horn, and legs from a deer, bob cat and much more. The goal of the trunk is to increase urban education through Project WILD activities. For further information see the list of general resources.

# Curriculum Implementation Plan

## Objectives:

Students will be able to:

1. identify urban mammal skulls with the aid of a key.
2. measure using metric units.
3. recognize specialized teeth in mammals.
4. develop an appreciation for scientific terms.
5. compare and contrast the mammal skulls for the needs of each species.

## Background:

Students need to have the 12 mammal skulls available. They can work in groups or individually. The skulls need to be handled gently and with caution since many are very fragile.

This lesson can be taught with existing units on mammals or the skeleton. Reference material can be obtained by using the general resources at the end of this document.
Finally, examination of the skulls and teeth can show characteristics which are similar in humans.
Once the skulls have been identified, ask the students questions about the physiology of each species. Have them write a conclusion as to why an armadillo has no incisors or canines yet it eats meat and plants. Another question might be why do the nocturnal mammals have such a wide interorbital width? The deer skull brings up the question as to why do some mammals have antlers or horns and most have nothing protruding from the skull. How are these specimens similar or different from our own skull? Do we have long sharp canines or long incisors? How have humans adapted the environment of today?

# How To Use the Skull Key

The identification of a mammal skull or jaw is made with the help of a "key". A key is a selection of features arranged in a sequence of alternatives, from which a choice must be made at each step of the sequence. By following through the series of choices correctly, you are guided to an identification. The key is arranged by a series of numbered steps, and at each step, two or more contrasting features are described, each indicated by a, b, c, or d. At most steps only two choices are offered.

The key uses a minimum of technical terms. All terms are listed in the glossary. Most measurements are only approximations. The measurements are given in centimeters (2.5cm equals 1 inch). All measurements are taken with the skull or jaw in a position such that the molar or cheek teeth are in a nearly horizontal position.

**Glossary of Terms:**

| | |
|---|---|
| Anterior | - toward the front of the skull or lower jaw bone. |
| Canine | -one of the four teeth in the front corners of the mouth. Canine teeth are usually large and pointed in meat-eating species, but may be small, or even absent, in plant eaters. They are the first (the most anterior) teeth in the maxilla, or upper jaw bone. In humans, they are sometimes called 'eye-teeth' because they are located just below the eyes. |
| Cheek Teeth | -Teeth rooted in the maxilla (upper jaw bone), behind the canines, along the sides of the mouth. They include both premolars and molars, and may have from 1 to 5 roots, depending on their size. In the lower jaw all teeth behind canines (or incisors, if canines are absent) are also cheek teeth. |
| Cranium | - the skull without the lower jaws. |
| Incisor | - tooth in the front of the mouth, between the canines. Incisors of the upper jaw grow from the premaxilla; all other upper teeth grow from the maxilla. |
| Interorbital width | -Distance between the upper edges of the orbits (eye sockets), measured across the top of the skull. |
| Jaw | - the lower jaw, or mandible; it is formed of the two dentary bones, one on each side. |

| | |
|---|---|
| Length of jaw | - greatest length of the lower jaw, measured from the front of the incisors to the most posterior point of the jaw, either at the angle of the jaw or at the condyle (movable joint where the jaw meets the skull). |
| Length of skull | - greatest length of the lower jaw, measured from the front of the incisors or from the most anterior part of the premaxilla, or nasals (which ever is most anterior), to the most posterior part of the skull. |
| Maxilla- | - bone forming major portion of the upper jaw on each side, and supporting the upper canines and the cheek teeth. |
| Nasal bones- | - from the upper surface of the rostrum, or muzzle, lying above the nasal openings. |
| Orbit- | - the eye socket. The size of the orbit can be determined by measuring its diameter, from rim to rim. The length of the orbit is its diameter from front to rear. |
| Posterior | - toward the back, or rear, of the skull or lower jaw. |
| Premaxilla | - forms the most anterior part of the skull, the front tip of the upper jaw, in front of the maxilla. Supports the incisor teeth, curves upwards toward the nasal bones. |

**For more information:**

*The Mammals of Texas,* by William B. Davis and David J. Schmidly ( Texas Parks and Wildlife, 1994)
The Golden Guide to Mammals, Golden Press, 1987
A Key Guide to Mammal Skulls and Lower Jaw Bones by Aryan I. Roest (Mad River Press 1991)
Skulls Unlimited- Moore OK
American Head Hunter-Dayton, TX
Moscow Trading Co.- Moscow, ID
R&R Trappers Supply- New Ulm, MN

# A Key to Urban Mammal Skulls

1- a. Large skull, over than 20cm: .......... go to step 2
b. Medium skull, 10-19cm: .......... go to step 3
c. Small skull, 3-9cm: .......... go to step 7
d. Tiny skull, less than 3 cm: .......... go to step 9

2- a. No canine teeth: .......... whitetail deer
b. long canine teeth: .......... coyote

3- a. canine teeth: .......... go to step 4
b. no canines or incisors: .......... armadillo

4- a. Molar row longer than 3.5cm: .......... go to step 5
b. Molar row 2-3cm: .......... go to step 6

5- a. 5 incisors, 6-7 cheek teeth: .......... opossum
b. 3 incisors, 6 cheek teeth,
braincase narrows toward the back: .......... raccoon

6- a. length of canine 3cm ,
inter orbital (eye socket) width 3cm: .......... bobcat
b. length of canine 1cm,
inter orbital width 2.5cm: .......... domestic cat

7- a. canine teeth: .......... go to step 8
b. no canine teeth: .......... rabbit

8- a. length of skull longer than 7cm: .......... skunk
b. length of skull less than 7cm .......... squirrel

9- a. skull chunky, 1 or 2 incisors on each side separated
in front of skull by a distinct notch: .......... bat
b. skull 2.5 cm long, incisors not notched
or grooved: .......... house mouse

## Cleaning Skulls

Some people may wish to order cleaned skulls from companies which deal in this trade. But for those who want to clean skulls which have been found, especially if the skulls are not broken and still have most of their teeth the following will help with the process.

If the skull or jaw bone is nearly stripped of flesh by insects when it is found, soaking in plain water for 24 hours and a simple brushing, with an old toothbrush, soap and running water, may be enough to clean it. Be sure all soft tissue is removed from the brain cavity and the nasal passages before allowing the scrubbed skull to dry.

If hair and meat are still attached to the skull, they should be removed. In most cases this is easily accomplished by cooking the skull. If it is a small skull, it can be dropped into boiling water for a few minutes; usually five minutes is enough. Then remove the skull from the boiling water (using forceps or tongs), hold it under cool running water, and pull off any bits of loose tissue with forceps, fingers. or whatever seems to work best. An old toothbrush is very useful here too.

Larger skulls should not be dropped into boiling water, since the sudden change in temperature may cause large teeth to split. They can be placed in cool water in a large pan, can or bucket to which a bit of detergent has been added to cut the grease. Place these on the stove or hot plate to warm or simmer-- no warmer. This should not be done in the kitchen -- the garage or outside is better. After several hours, or overnight, or even several days if the skull is very large, the soft tissue can be easily removed from the skull bones. A little trimming by hand under running water, and some brushing with a small brush will produce a nice cleaned skull.

Cleaned skulls can be left in the sun for a few days to dry and bleach a bit. They can also be soaked, for a few minutes only, in a solution of hydrogen peroxide (1/2 cup per gallon of water) to whiten them. After a brief soaking, allow the skull to dry without rinsing. Commercial bleaches should be used only as a very dilute solution with water since they tend to cause the bones to be brittle and leave a crusty sediment.

Skulls can also be cleaned by allowing them to rot in water, without heating or cooking. But this is a very smelly process. The results are excellent but allow enough time for all the soft tissue to be rotted away. Avoid letting flies get to the soft tissue of a fresh skull. They may lay eggs on the flesh, which quickly develop into maggots, and the maggots will clean the skull of tissue. However, they also release materials which may stain or discolor the underlying bone.

# For More Information

## General Resources

Acorn Naturalist
17300 East 17th St. # J-236
Tustin, Ca 92680

American Headhunter
P.O. Box 61
Dayton, Tx 77535
(409) 258-3102

Bat Conservation International
P.O. Box 162603
Austin, Tx 78716
1-800-538-BATS

City Kids and City Critters! by Janet Wier Roberts and Carole Huelbig (McGraw Hill, 1996)

Furs Plus/ Don Cooper
P.O. Box 1107
Lindale, Tx 75771
(903) 882-4294

The Fur Bearers of Texas by David J. Schmidly (Texas Parks and Wildlife Department Bullitin No. 111)
Golden Guide to Mammals by Herbert S. Zim and Donald F. Huffmiester (Golden Press, New York, 1987)

The Kids' Wildlife Book by Warner Shedd (Williamson Publishing, 1994)

Learn about...Texas Indians by Georg Zappler and Elena T. Ivy (Texas Parks and Wildlife Press, 1996)

The Mammals of Texas by William B. Davis and David J. Schmidly (Texas Parks and Wildlife Department, 1994)

Moscow Hide and Fur
P.O. Box 8918
Moscow, Idaho
(208) 882-0601

OBIS- Outdoor Biology Instructional Strategies
Delta Education
P.O. Box 915
Hudson, N.H. 03051-0915

Pawtographs
Michael Huges
209 Post Creek Rd
Nashville, Tn 37221

Peterson's First Guide to Urban Wildlife by Sarah B. Landry (Houghton Mifflin Co., 1994)

Project WILD
5430 Grosvenor Ln.
Bethesda, Md 20814
(301) 493-5447
Email- natpwild@igc.apc.org

Rocky Mountain Elk Foundation
2291 West Broadway
P.O. Box 8249
Missoula, Mt 59807-8249
1-800-CALL-ELK

R&R Trapper's Supply
1405 North Broadway
New Ulm, Mn 56073
(507) 354-5318

Sharing Your Space
Dakota Department of Game, Fish and Parks

Skulls Unlimited International
P.O.Box 6741
Moore, Ok 73153
1-800-659-SKULL

Texas Memorial Museum Publications
The University of Texas
2400 Trinity
Austin, Tx 78705

Texas Parks and Wildlife Department
4200 Smith School Road
Austin, Texas 78744
1-800-792-1112
Web Site
http://www.tpwd.state.tx.us

Texas Wildscapes, Backyard Wildlife Habitat Packet (Texas Parks and Wildlife Department Nongame and Urban Program, 4200 Smith School Rd, Austin, Tx 78744)

Take Along Guide Tracks, Scats and Signs by Leslie Dendy (Northwood Press, Inc., Minocqua, Wisconsin, 1995)

Zoobooks
P.O. Box 85271
San Diego, Ca 93128

# WILD in the CITY-The Urban Jungle

**Hands-on activities for students and educators learning about urban wildlife of Texas**

## Introductory Packet

### Acknowledgments

WILD in the City and Project WILD wish to thank the following businesses and individuals who generously helped put together the WILD in the City-The Urban Jungle trunks for educators in Texas:

Wild Basin Preserve- Austin, Tx

The American Head Hunter-Paul Micallef

R&R Trapper's Supply

Furs Plus- Don Cooper

Johnny Stewart Game Calls-Waco, Tx- Gerald Stewart

Skulls Unlimited- Moore, Ok

Texas Memorial Museum- University of Texas at Austin

**Special thanks to the Texas Parks and Wildlife Department and to these individuals who were especially helpful:**

Donnie Harmel - Kerr Wildlife Management Area- Hunt, Tx
Susan Harris - ISS, Austin, Tx
Elena Ivy - Public Lands, Austin, TX
Juliann Pool - Public Lands, Austin, TX
Ray Whitney - Urban Biologist, Cedar Hill, Tx
Paul Hope - Retired, Austin, TX

# General Information

The WILD in the City program is part of an effort by the Texas Parks & Wildlife Department to bring the world of wildlife to inner-city students across the state. This program was created in 1995 by the nationally renowned Project WILD program which is a K-12 conservation and environmental education program emphasizing wildlife. Through a $6,000 grant provided by the Phillips Petroleum Company and the National Fish and Wildlife Foundation the Texas Project WILD office has created the "WILD in the City--the Urban Jungle" program.

These trunks have been designed to assist educators in developing lesson plans that will spark student interest in urban mammals such as the grey squirrel, bat, opossum, raccoon, whitetail deer, cotton tail rabbit, coyote, armadillo, mouse, and skunk and wildlife conservation. The trunk design allows for an interactive learning approach through the use of hands on activities and lessons from programs such as Project WILD, OBIS, National 4-H, and books such as *The Kids' Wildlife Book*, *Introducing Mammals to Young Naturalists* and *Zoobooks*. These books have been referenced by tabs placed on the appropriate page for easy guidance to the background information and activities.

The trunks have been designed for use by teachers and educators with students in grades K-12. However, there are more applications for the upper elementary and middle school level students.

Teachers may use some or all of the activities/presentations in the trunks to enhance their classroom lessons.

Trunks are available from Texas Parks and Wildlife Department on a first come first serve basis and the loan period is not to exceed three weeks.

The trunk may be picked up and returned to the urban wildlife offices of theTexas Parks and Wildlife Department urban biologists office nearest your school.

All borrowers must complete a Receipt for property. This holds the borrower responsible for the trunk and its contents from theft or loss. The replacement cost for each trunk is $1000. Individual item cost varies and may be purchased to replace those that become lost or damaged while the trunk is in your possession.

The trunks contain valuable items and should be kept locked, in a secure place when not in use.

A teacher evaluation form is enclosed in the trunks to allow for teacher comment and to provide the Texas Parks and Wildlife Department with suggestions on how to better assist educators in their missions. Borrowers are encouraged to complete the evaluation form.

For more information about how you can receive the Project WILD activity guide please contact:

Texas Parks & Wildlife Department
attn: Project WILD coordinator
4200 Smith School Road
Austin, TX 78744
800-792-1112 ext. 64

## Trunk Components Checklist

____ Slide Show (14 slides, script)
____ *Introducing Mammals to Young Naturalists*
____ *The Kids' Wildlife Book*

____ 1. **Mammals**
- ____ *Golden Guide to Mammal*
- ____ *"Bats" Zoobook*
- ____ A Key to Urban MammalSkulls
- ____ 9 mammal skins/furs
- ____ Bones and Teeth
- ____ "Dilly of a 'Dillo" Project WILD Activity
- ____ *Mammials of Texas*
- ____ *Fur Bearers of Texas*
- ____ 12 Skulls
- ____ Tape Measure

____ 2. **Mammal Sign**
- ____ *Take Along Guide to Tracks, Scat and Sign*
- ____ 9 Scat Replicas
- ____ Bobcat Leg with paw
- ____ "Tracks!" Project WILD activity
- ____ Coyote skin with legs and foot
- ____11 Track Replicas
- ____ Deer Leg with hoof

____ 3. **Mammal Survival**
- ____ Deer Call ____ Squirrel Call ____ Sound Safari Cassette Tape
- ____ *"Night Animals" Zoobook* (available early 1997)
- ____ "Quick Frozen Critters" Project WILD Activity
- ____ OBIS activities "Sound Off", Silent Stalking", "Invent and Animal"

____ 4. **Deer**
- ____ *"Deer Family" Zoobook*
- ____ 5 Jawbones
- ____ How to Age Deer Activity
- ____ Learn About Whitetails, TPWD publication
- ____ "Oh Deer" Project WILD Activity
- ____ Body Language Silhouettes Cards and key
- ____ "Deer Crossing" Project WILD Activity
- ____ Antlers
- ____ Cow Horn

____ 5. **Hides**
- ____ 9 Mammal Skins
- ____"Make A Coat" Project WILD Activity
- ____ Moccasin Pattern

## Code for Skulls, Tracks, Scats, and Furs:

I. Armadillo

II. Bat

III. Bobcat

IV. Coyote

V. Deer

VI. Domestic Cat

VII. Mouse

VIII. Opossum

IX. Rabbit

X. Raccoon

XI. Skunk

XII. Squirrel

# WILD in the CITY
## Trunk Evaluation Form

Thank you for your interest in WILD in the CITY. Texas Parks and Wildlife Department and Project WILD are interested in your response to the project. Your feedback will help us evaluate the program and make improvements. Please include your name and address so we can keep you updated with additional information and services that we may offer in the future. Please photocopy this form, then fill out and send the copy to:

Texas Parks & Wildlife Department
Attn. Project WILD Coordinator
4200 Smith School Road
Austin, Tx 78744

Please Print

Name:______________________________ Male___ Female___

Ethnicity_____

School Name:__________________________

Your Students' Grade Level______

School Address: ________________________________________

________________________________________________________

Home Address:__________________________________

________________________________________________________

________________________________________________________

How did you hear about WILD in the CITY?

____the Project WILD coordinator

____attended a WILD in the CITY workshop

____other_______________________________________________

Please rate the trunk materials on a scale of 1-5 (one being the best rating):______

Were the materials age-appropriate? yes____ no____

Why or why not?

________________________________________________________

________________________________________________________

________________________________________________________

Did the WILD in the CITY materials blend into your regular lesson plans?

yes ____ no ____ Why or why not?

________________________________________________________

________________________________________________________

________________________________________________________

____ "What You Wear Is What They Were" Project WILD Activity

____ 6. **Urban Nature Search**

____ *Peterson's First Guide to Urban Wildlife*

____ Wildscapes Information Packet

____ National 4-H Wildlife Project

____ "Urban Nature Search" and "Wildwork" Project WILD Activities

____ " Microtrek Treasure Hunt" Project WILD Activity

## WILD in the CITY Slide Show

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# 1- MAMMALS

**Background:** Each species of mammal is especially adapted to its way of life, (where it lives, what it eats, etc.), but all mammals share certain characteristics. Mammals are warm- blooded vertebrates that have hair and produce milk to feed their young. Some mammals eat plants (herbivores), some are meat eaters (carnivores), and others have a diet of both plant and animal (omnivores). Because mammals have this varied diet they also have specialized teeth. Front teeth called incisors, bite and cut. Predators such as bobcats have sharp pointed canine teeth next to the incisors to grip and tear. Premoloars and molars are used to shred, grind, and crush by animals like deer, rabbits, squirrels, opossums and skunks.

**For more information:** *Little Golden Guide To Mammals*, *Mammals of Texas*, *The Kids' Wildlife Book*, *Introducing Mammals To Young Naturalists*, and *Fur Bearers of Texas*

## Materials and Objectives

**For these activities, you will need:**

*Little Golden Guide to Mammals*, *Mammals of Texas*, and *Kids'Wildlife Book*
Mammal skulls, bones, and teeth
Tape Measure
A Key to Urban Mammal Skulls
Mammal Hides
"Dilly of a 'Dillo" activity adapted from Project WILD
Giant Armadillo and Grid Transparency
Carpenter's Chalk Line and Chalk

**In this segment, students will learn:**

-Body structure and parts of mammals
-Differences between a predator skull and a prey animal skull
-Identification of different mammal skulls, bones and fur
-Measurement skills needed to compare and contrast mammal sizes and proportion

**What to do:**

1. Examination: Look at and handle the hides, skulls, teeth, and bones from the trunk. What characteristics do these samples have in common? What differences do they display?
2. Diet: Look at the teeth on each skull. Can you tell which mammals eat meat (carnivores)? Which eat plants (herbivores)?

3. Identify: Use the skull key to key out the mammal skulls. Which skull belongs to which urban mammal?

4. Research about size and structure: Read through *The Kids' Wildlife Book* , *The Little Golden Guide to Mammals*, *The Mammals of Texas* and *Introducing Mammals to Young Naturalists* for more interesting facts on body structure and characteristics of mammals. What might allow some mammals to live in the city and others to avoid the urban areas?

6. "Dilly of a Dillo": The class can create a life-size prehistoric giant armadillo based on the Aquatic WILD activity "Whale of a Tail". Discuss the structure and size of the Ice-Age mammal and the challenges and needs of such a large animal compared to the modern armadillo and ourselves.

# A Key to Urban Mammal Skulls

1- a. Large skull, over than 20cm: .................... go to step 2
b. Medium skull, 10-19cm: .................... go to step 3
c. Small skull, 3-9cm: .................... go to step 7
d. Tiny skull, less than 3 cm: .................... go to step 9

2- a. No canine teeth: .................... whitetail deer
b. long canine teeth: .................... coyote

3- a. canine teeth: .................... go to step 4
b. no canines or incisors: .................... armadillo

4- a. Molar row longer than 3.5cm: .................... go to step 5
b. Molar row 2-3cm: .................... go to step 6

5- a. 5 incisors, 6-7 cheek teeth: .................... opossum
b. 3 incisors, 6 cheek teeth,
braincase narrows toward the back: .................... raccoon

6- a. length of canine 3cm ,
inter orbital (eye socket) width 3cm: .................... bobcat
b. length of canine 1cm,
inter orbital width 2.5cm: .................... domestic cat

7- a. canine teeth: .................... go to step 8
b. no canine teeth: .................... rabbit

8- a. length of skull longer than 7cm: .................... skunk
b. length of skull less than 7cm .................... squirrel

9- a. skull chunky, 1 or 2 incisors on each side separated
in front of skull by a distinct notch: .................... bat
b. skull 2.5 cm long, incisors not notched
or grooved: .................... house mouse

## How To Use the Skull Key

The identification of a mammal skull or jaw is made with the help of a "key". A key is a selection of features arranged in a sequence of alternatives, from which a choice must be made at each step of the sequence. By following through the series of choices correctly, you are guided to an identification. The key is arranged by a series of numbered steps, and at each step, two or more contrasting features are described, each indicated by a, b, c, or d. At most steps only two choices are offered.

The key uses a minimum of technical terms. All terms are listed in the glossary. Most measurements are only approximations. The measurements are given in centimeters (2.5cm equals 1 inch). All measurements are taken with the skull or jaw in a position such that the molar or cheek teeth are in a nearly horizontal position.

**Glossary of Terms:**

| | |
|---|---|
| Anterior | - toward the front of the skull or lower jaw bone. |
| Canine | -one of the four teeth in the front corners of the mouth. Canine teeth are usually large and pointed in meat-eating species, but may be small, or even absent, in plant eaters. They are the first (the most anterior) teeth in the maxilla, or upper jaw bone. In humans, they are sometimes called 'eye-teeth' because they are located just below the eyes. |
| Cheek Teeth | -Teeth rooted in the maxilla (upper jaw bone), behind the canines, along the sides of the mouth. They include both premolars and molars, and may have from 1 to 5 roots, depending on their size. In the lower jaw all teeth behind canines (or incisors, if canines are absent) are also cheek teeth. |
| Cranium | - the skull without the lower jaws. |
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| Interorbital width | -Distance between the upper edges of the orbits (eye sockets), measured across the top of the skull. |

| | |
|---|---|
| Jaw | - the lower jaw, or mandible; it is formed of the two dentary bones, one on each side. |
| Length of jaw | - greatest length of the lower jaw, measured from the front of the incisors to the most posterior point of the jaw, either at the angle of the jaw or at the condyle (movable joint where the jaw meets the skull). |
| Length of skull | - greatest length of the lower jaw, measured from the front of the incisors or from the most anterior part of the premaxilla, or nasals (which ever is most anterior), to the most posterior part of the skull. |
| Maxilla | - bone forming major portion of the upper jaw on each side, and supporting the upper canines and the cheek teeth. |
| Nasal bones | - from the upper surface of the rostrum, or muzzle, lying above the nasal openings. |
| Orbit | - the eye socket. The size of the orbit can be determined by measuring its diameter, from rim to rim. The length of the orbit is its diameter from ront to rear. |
| Posterior | - toward the back, or rear, of the skull or lower jaw. |
| Premaxilla | - forms the most anterior part of the skull, the front tip of the upper jaw, in front of the maxilla. Supports the incisor teeth, curves upwards toward the nasal bones. |

**For more information:** *The Mammals of Texas*, Skulls Unlimited, American Head Hunter, Moscow Trading Co., R&R

## Cleaning Skulls

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## 2- MAMMAL SIGN

**Background:** One of the best ways to determine where animals have been is to look for their tracks and signs that are left behind. Tracks can tell you where the mammal feeds and rests, their travel routes, and how fast they were traveling. Tracks can also tell you how many animals live in an area at a given time of year. Some of the signs left behind are tree rubs, scat (droppings), antlers, broken shells and seeds, and bones.

**For more information:** *Take Along Guide to Tracks and Scat*, *Introducing Mammals To Young Naturalists* , *The Kids' Wildlife Book*, and Project WILD "Tracks!" activity

## Materials and Objectives

**For these activities, you will need:**

*Take Along Guide to Tracks and Scat*
*The Kids' Wildlife Guide*
Track Replicas
Scat Replicas
Coyote and Deer leg
Bobcat foot
Raccoon Foot
Project WILD "Tracks!" activity

**In this segment, students will learn:**

-What signs indicate the presence of mammals
-Identify each urban mammals' sign and track
-Determine why mammals leave some of the signs they do
-Size and shape of urban mammals tracks
-Structure of urban mammals feet

**What to do:**

1. Look at the legs and feet and track samples. Which one came from which mammal? How are hoofs different from claws?
2. Plaster tracks: Follow the instructions for the Project WILD activity "Tracks!" to create plaster tracks.
3. Comparisons: Draw or find pictures of other wildlife that lives in your area. Compare mammal tracks to those of other animals.
4. Look at the difference between the various mammal scat. How do you tell a carnivore or omnivore's scat from an herbivore's?
5. Reasons for sign: Why do deer rub trees? Why might coyote scat change in consistency upon the season?

6. Hunt for sign: Next time you are out for a hike, look for animal sign. If it's something you can take a picture of or carry back to you classroom, share it with the rest of your class. See if you can identify the animal that left the sign and what it might have been doing at the time. (**Remember**: In some places, like national parks, it is illegal to remove natural objects like deer antlers.)

# 3- MAMMAL SURVIVAL

**Background:** In nature, there are no good or bad animals. There are those animals which kill to eat (predators) and those which are killed and eaten (prey). When a coyote chases, catches, kills and eats the rabbit, it is not being cruel. It is only meeting its physical need for food. Its meal could also be a mouse, rat or other small creature if one of them had been closer or easier to catch. Some animals have adapted to their surroundings and nature by being night creatures (nocturnal) to avoid being prey. While other mammals have developed sounds to communicate with each other to warn of danger or intimidate their enemy.

**For more information:** *Night Animals Zoobook*, *Bats Zoobook*, *Introducing Mammals to Young Naturalists* and *The Kids' Wildlife Book*

## Materials and Objectives

**For these activities, you will need:**

Mammal skulls
Sound Safari cassette tape (available in early 1997)
animal calls
Project WILD "Quick Frozen Critters" activity
OBIS activities: "Sound Off", "Silent Stalking", and"Invent an Animal"
*Night Animals Zoobook*
*Bats Zoobook*

**In this segment, students will learn:**

-Mammal adaptations for survival
-Nocturnal vs. diurnal vs. crepuscular animals
-Predator/ Prey relationships
-Sounds and calls of some urban mammals
-What the different animal sounds mean
-How to make animal sounds

**What to do:**

1. Observation: Compare the skulls to discover which mammal is a nocturnal animal. Which skulls are from nocturnal mammals? Which are diurnal? Which are both diurnal and nocturnal or crepuscular? (see *"Night Animals" Zoobook*)

2. Listening and Identifying: Use your sense of hearing while carefully listening to the Sound Safari cassette tape. Which animals make which sounds? Why do animals make sounds? (see references above)

3. Imitation: Try to make the animal call using the provided calls. If you have a park or wooded area near by, try calling in predators to

your prey sounds. When will a squirrel make the barking sound? When will the doe bleat?

4. Adaptation: Do the Project WILD activity, "Quick Frozen Critters" or the night time OBIS activities "Sound Off" and "Silent Stalking". How difficult is the life of a nocturnal animal? Can people adapt? Are humans a better predator or prey animal?

# 4- DEER

**Background:** White-tailed deer get their common name by the warning sign of their white trimmed ten inch tail held upright when they are frightened or nervous. Deer are very adaptable and can live in a variety of different habitats where an abundance of green plants is found. Deer eat mostly browse (leaves, twigs, young shoots of woody plants, and vines) and forbs (broadleaf flowering plants). Male animals of the deer family, deer, elk, moose, and caribou, produce antlers each year while cows, goats, antelope, and others grow horns. Horns and antlers both extend from the head area as hard objects but they grow differently. A horn has a bony center and is made of cells called keratin (the same substance that hair and fingernails are made of). Horns are infrequently shed and both males and females may grow them. Most hoofed animals like cattle, sheep, and goats grow horns. Antlers are solid bone and are grown only by the deer family. Antlers are shed each year and must be regrown the following year.

**For more information:** *Deer Family Zoobook*, *Learn about Whitetails*-TPWD publication, *Whitetail Body Language-*, *Introducing Mammals To Young Naturalists*, and *The Kids' Wildlife Book*

## Materials and Objectives

**For these activities, you will need:**

Whitetail Body Language publication
Silhouette cards and silhouettes answer key
Deer antlers, jaws, and cow horns
Learn About Whitetails publication
Determining the Age of Deer Texas -Agriculturial Extension Service
Whitetail Wonders Publication
*Deer Family ZOOBOOK*
Project WILD "Oh, Deer!" and "Deer Crossing" activities

**In this segment, students will learn:**

-To identify body postures as a form of deer communication
-What the different postures look like
-Differences between antlers and horns and what they are made of
-How animals use antlers and horns
-How to age deer by looking at their teeth
-Components of deer habitat
-Define limiting factors
-Evaluate alternatives and consequences with issues involving wildlife

**What to do:**

1. Using body language: Look around the room and describe the body language of others around you. Have students use their body language to convey a message to another student.
2. Matching: Match the deer silhouettes with the body language description. Then check yourself against the answer key and read the full description of the postures in the "Whitetail Body Language" publication. Why and when will animals use body language?
3. Reasons for body language: Act out or discuss situations in which deer or other mammals need to use the various postures.
4. Identification: Identify what animal each horn or antler came from. For what purposes do animals use their antlers and horns? (use references stated above)
5. Aging animals: You can age a bighorn sheep by counting the number of rings on its horn. Can you age a deer by counting its points? Why or why not? Use the Learn about Whitetails publication "How to Age Deer" guide. How can you age a deer?
6. Aging Deer: Use the jawbones of the deer with the "How to Age Deer Guide". How old were the deer? How do the jawbones and teeth change with age?
7. Compatibility: Do the Project WILD activities "Oh, Deer!" and "Deer Crossing". What will the future bring to the urban deer? Can humans and deer co-habitat?

## 5- HIDES

**Background:** All mammals have true hair. Their skin or hide provides protection from the weather, (heat, cold, water, etc.) and this layer contains many specialized cells and glands including sweat, scent, fat, and hair. Hair may help the animal feel, like the whiskers on a cat or they may act as as camouflage to help the mammal blend into the surroundings like the spots on a new fawn. Humans have used animal skins for their own protection against the weather and for utensils and tools for thousands of years.

**For more information:** *Introducing Mammals to Young Naturalists* , Project WILD "Make A Coat!" and "What You Wear Is What They Were" activities, *Fur Bearers of Texas* and *The Kids' Wildlife Book*

### Materials and Objectives

**For these activities, you will need:**

Hides and furs

Historic Uses of Deer List

Project WILD activities-"Make A COAT!" and"What You Wear Is What They Were"

Moccasin pattern

*The Kids' Wildlife Book* "Pouch Pattern" p. 22

**In this segment, students will learn:**

- Structure of mammal hide and hair
- To identify furs and skins of different mammals
- Present and historical/cultural uses of mammal hides and other body parts

### WHAT TO DO:

1. Identify: Which skin or hide belongs to which mammal?
2. Uses for mammal skins: Have students drape the coyote skin and deer hide over their bodies. Compare the difference between cotton/polyester clothing to the coats made of the animal skin. What are some uses, past, and present, of mammal hides? Are parts of a hide better for some uses than others? (use references listed above for more Native American uses of mammals and the hides).
3. "Make A Coat!", "Make a Moccasin", "Make a Pouch": Use the Project WILD activity, Moccasin pattern and *The Kids' Wildlife Book* pouch pattern to make clothing and tools. You can fashion them out of brown packaging paper or paper bags. To soften the paper and make

it look like leather, dampen and crinkle it up, then spread it out to dry for a while.

4. Renewable or not? Use Project WILD activity "What You Wear is What They Were" to learn about natural resources and renewable vs. nonrenewable resources.

# 6- URBAN NATURE SEARCH

**Background:** Wildlife is not just the large animals like cougars, mountain lions, and bears. Wildlife includes all animals that have not been domesticated by people. Domesticated animals are those which have been tamed, made captive and bred for special purposes. Farm animals and pets are considered to be domesticated animals. Wild animals are all the rest. Wildlife is important in urban areas for numerous reasons. People can understand themselves by observing and sharing space with wildlife. Animals can also be an indicator of the health of what is occurring in our environment. The natural laws that influence wildlife deal with the animals habitat- food, water, cover, and space. Animals that do not find an appropriate habitat environment will either starve, be preyed upon, be unable to nurture young or progress to a better environment.

**For more information:** Texas Parks & Wildlife "Wildscapes" Packet, *Peterson's First Guide to Urban Wildlife*. National 4-H Wildlife Project- *"Urban and Backyard Wildlife"* and *The Kids' Wildlife Book*

## Materials and Objectives

**For these activities, you will need:**

*Peterson's First Guide to Urban Wildlife*

Texas Parks & Wildlife Department's Wildscapes information

Project WILD "Urban Nature Search" and "Microtrek Treasure Hunt" activities

4-H Wildlife Projects "Urban and Backyard Wildlife" and "Wildlife Observations""

Project WILD "Wildwork" activity

**In this segment, students will learn:**

-Observation skills for recognizing wildlife
-To identify forms of wildlife other than urban mammals
-Each environment has characteristic life forms
-Humans and wildlife share environments
-How students can help the wildlife in their environment
-About careers in Wildlife Management

**What to do:**

1. Treasure Hunt!: Follow the Project WILD activity, "Microtrek Treasure Hunt". How can "evidence" be used to interpret environments?

2. Classify: Make a questionnaire/survey for the Project WILD "Urban Nature Search" activity. The survey might include topics relating to: looking for evidence of predator/prey relationships,

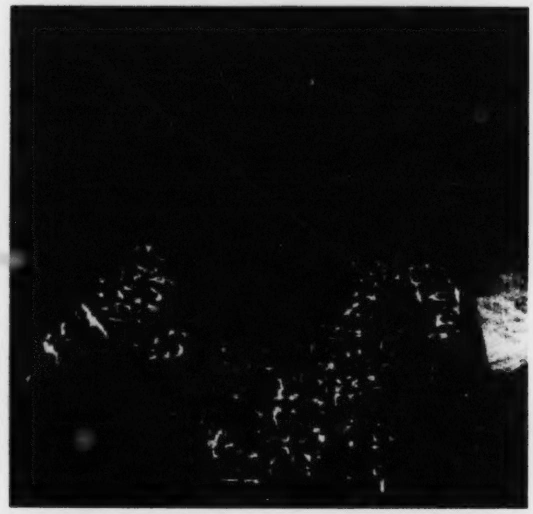
attempting to determine which animal is the predator or prey, looking for evidence of a food chain, or tracing water's path in an area. What types of wildlife are found around the school? Your home?

3. List: From the previous activities make a chart describing what you to do to keep these forms of wildlife healthy or encourage more wildlife to come to your environment. Where would these animals find food? Shelter? Water?

4. Take Action! : Using TPWD wildscapes information add a source of food, water or cover for your urban Wildlife.

4. Careers: Use the Project WILD activity "Wild Work" to explore future employment options in the field of wildlife. What training and qualifications are necessary to have a job working with animals and wildlife? Contact the personnel offfice of the Texas Parks and Wildlife Department. (See resources page for addresses and further information).

**Dina Armstrong**
**Mathematics**
**Central Middle School, Galveston ISD**



**University of Texas Medical Branch**
**Public Health, Galveston**
**Dr. Todd Miller, Mentor**

# Dina F. Armstrong

SCHOOL DISTRICT: Galveston Independent School District
SCHOOL: Central Middle School
SUBJECT: Mathematics
INTERNSHIP LOCATION: University of Texas Medical Branch at Galveston

## ABSTRACT

The summer internship that I participated in was housed in the Preventive Medicine and Community Health Department. This department enables scientists to apply theories and methods of the social and behavior sciences to the study of factors related to health promotion, risk of illness and the delivery of health services. I had several mentors with whom I worked with for a period of two weeks each. This put me in a self-study mode with plenty of help from all mentors.

The first area of study was on Flaws and Fallacies in Statistical Thinking. Students will investigate ways that data can be misrepresented through graphs and percent. The second area of study was devoted to the methods of clinical research. Students will conduct an experiment using similar methods of a clinical researcher. The third area of study was on the measures of risk. Students will poll a group of subjects on a particular risk factor questionaire and compute the absolute risk, relative risk, attributable risk and attributable risk percent on this group of subjects.

# Curriculum Implementation Plan

*OBJECTIVE: TLW:*

1 Develop critical thinking skills
2 Learn sequencing and ordering
3 Identify the three measures of central tendencies.
4 Explore two ways for finding mean of a set of data
5 Identify the measures of dispersion
6 Identify the measures of relationships between two or more variables.
7 Conduct a rudimentary experiment using statistics
8 Promote social growth
9 Improve writing skills

*MATERIALS*

1. Graph paper
2. scales
3. yard sticks
4. special forms (provided in plan)
5. cartoons on percent misrepresentation (provided in plan)

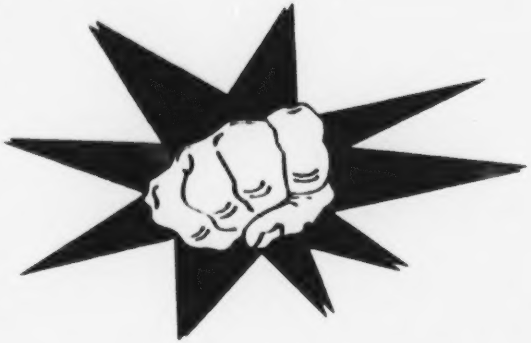
***PROCEDURES:* Students will enhance social skills by performing taks in groups.**

***ACTIVITIES:* conduct survey on cafeteria food preferencs.**

***Make graphs to show results:***

1. Each group discuss his graph
2. Lecture of JTPA experiment
3. Practice worksheet
4. Measure classmates weight and height
5. Make a scatter diagram
6. Make a frenquency distribution table with intervals
7. Find the mean of raw and grouped data
8. Find the measure of dispersion (range)
9. Calculate Pearson r
10. Write an article on the results of statistical data

BEST COPY AVAILABLE



# Persuasions

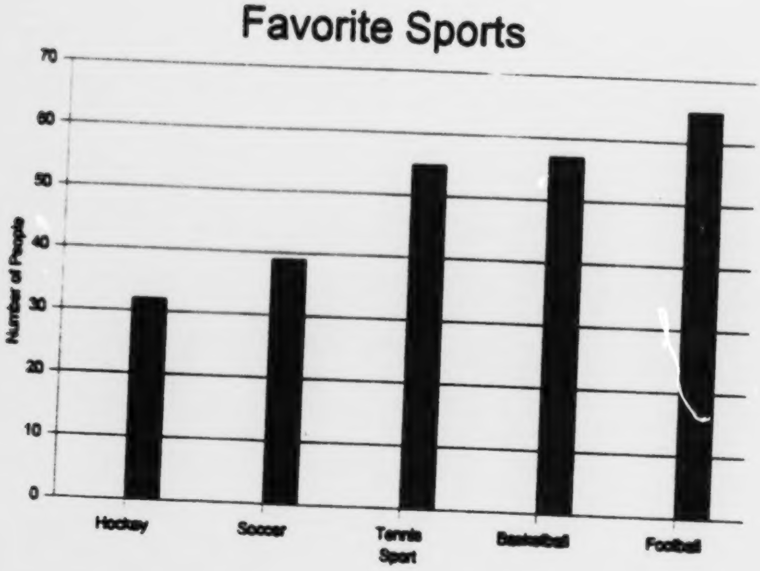
## Flaws and Fallacies

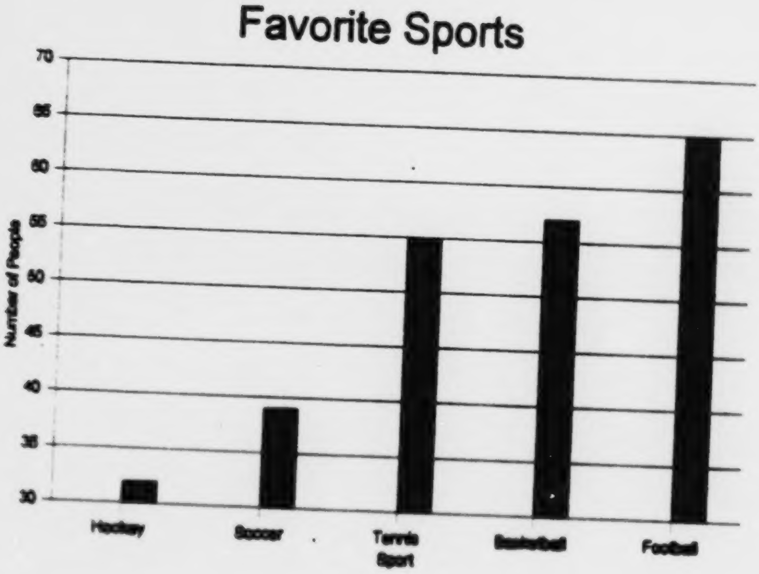
Statistics is a set of methods used to gather, organize, present and analyze numerical facts. However, it is sometimes difficult to make sense of massive data. This difficulty is the precise reason that graphs and charts are so often used to convey information. Sometimes graphs are employed to mislead the reader. This can be accomplished by manipulation of the vertical and horizontal axes of a graph. Through this manipulation, one can convey almost any desired impression.

Consider graph I and II titled "Favorite Sports." Which graph would you project if you definitely did not want a hockey team in your school?

# The Manipulative Axis

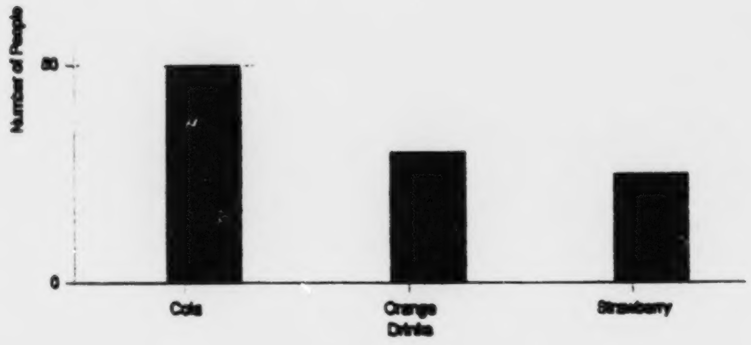
# The Manipulative Axis



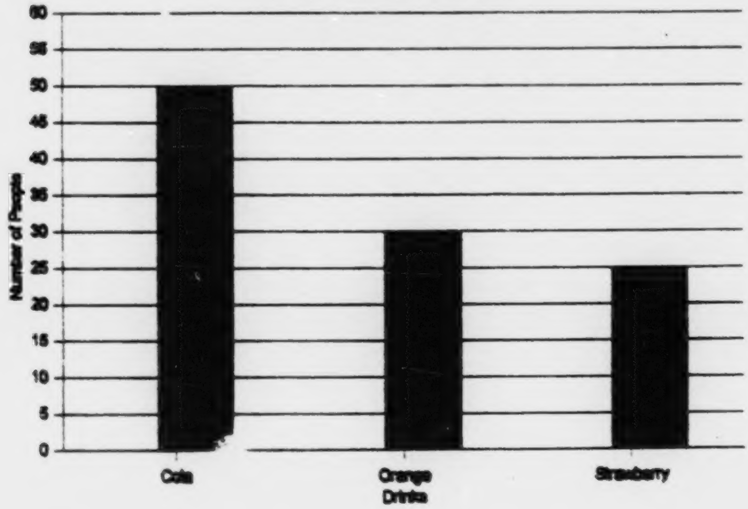


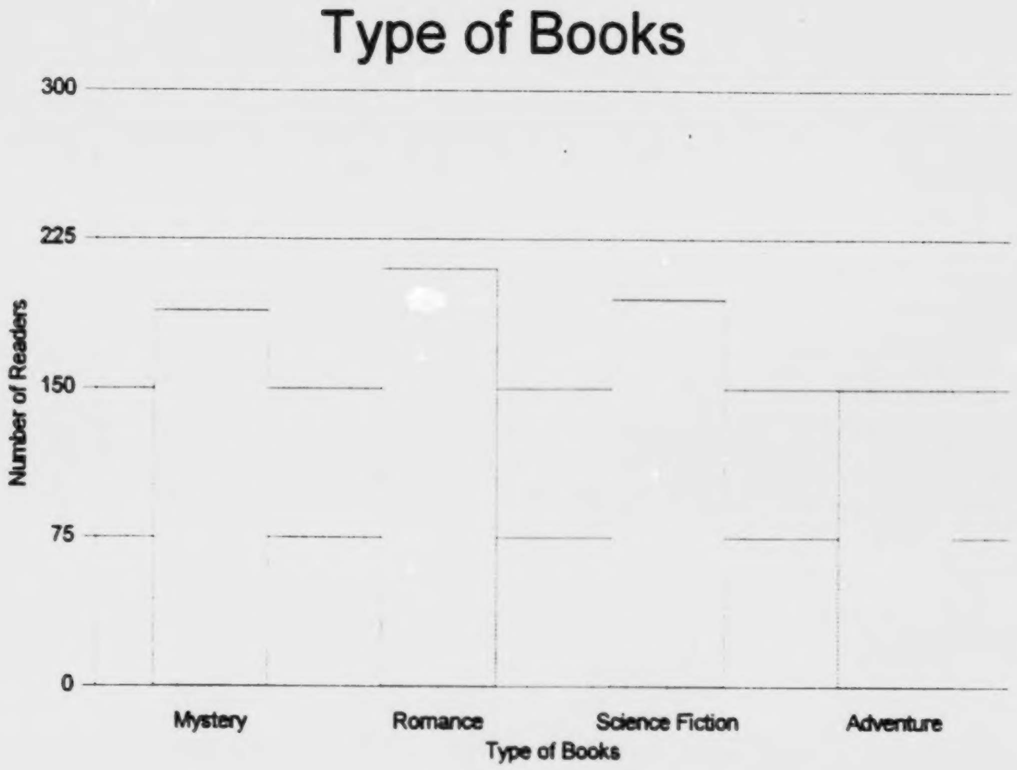
# The Manipulative Axis

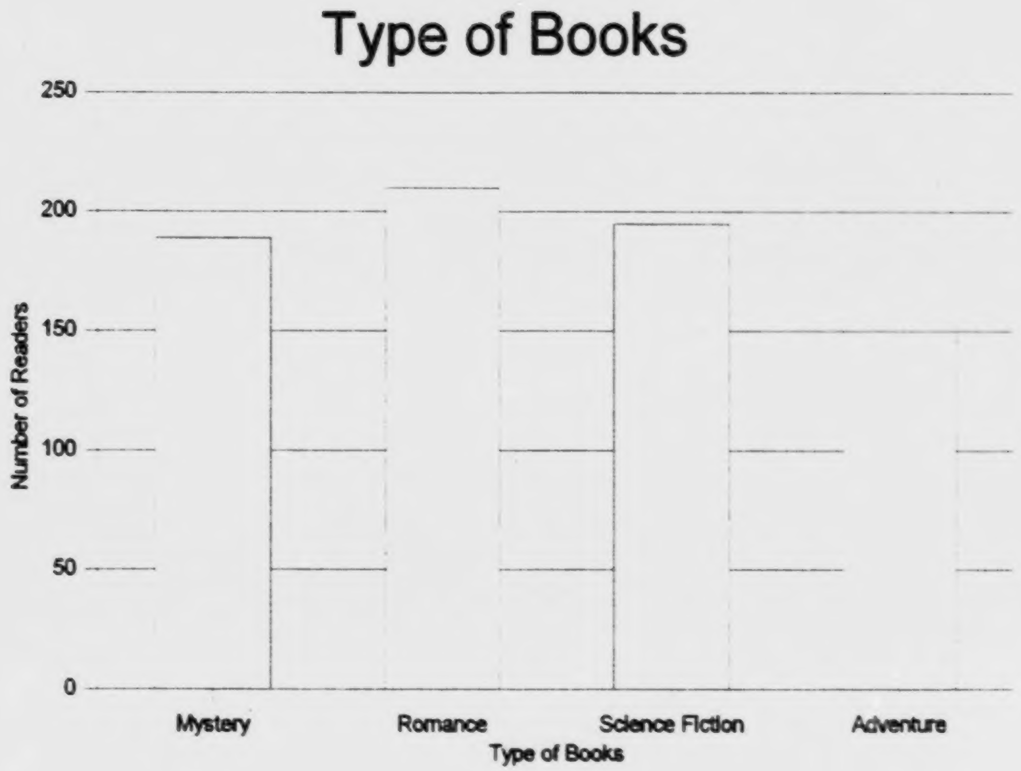
Favorite Drinks



Favorite Drinks




Type of Books
300
225
150
75
0
Number of Readers
Mystery
Romance
Science Fiction
Adventure
Type of Books


Type of Books
250
200
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100
50
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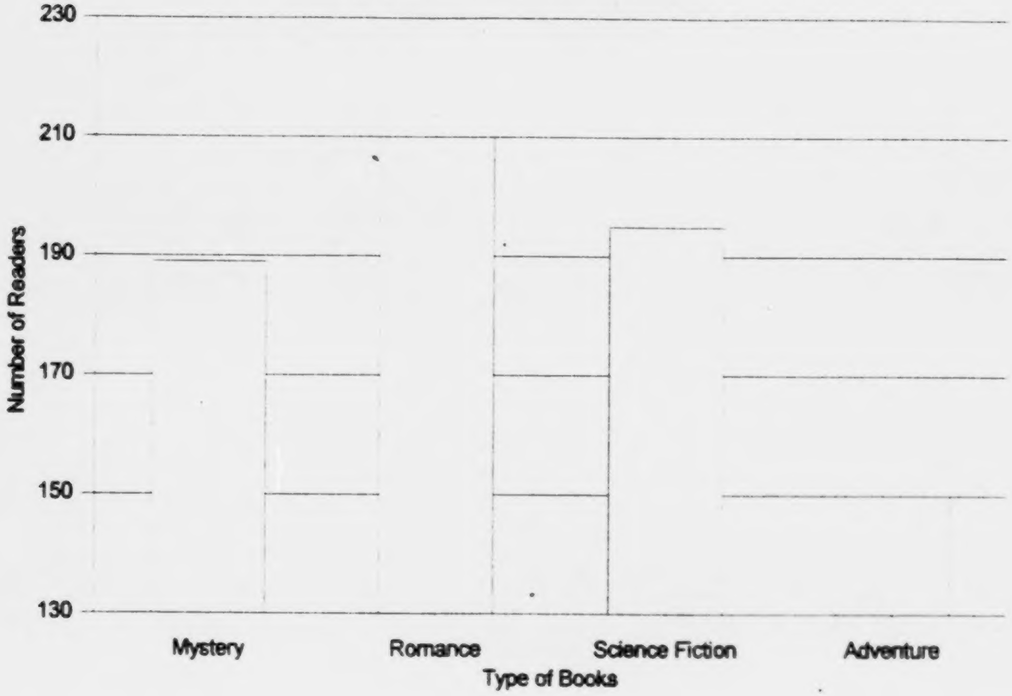
Number of Readers
Mystery
Romance
Science Fiction
Adventure
Type of Books



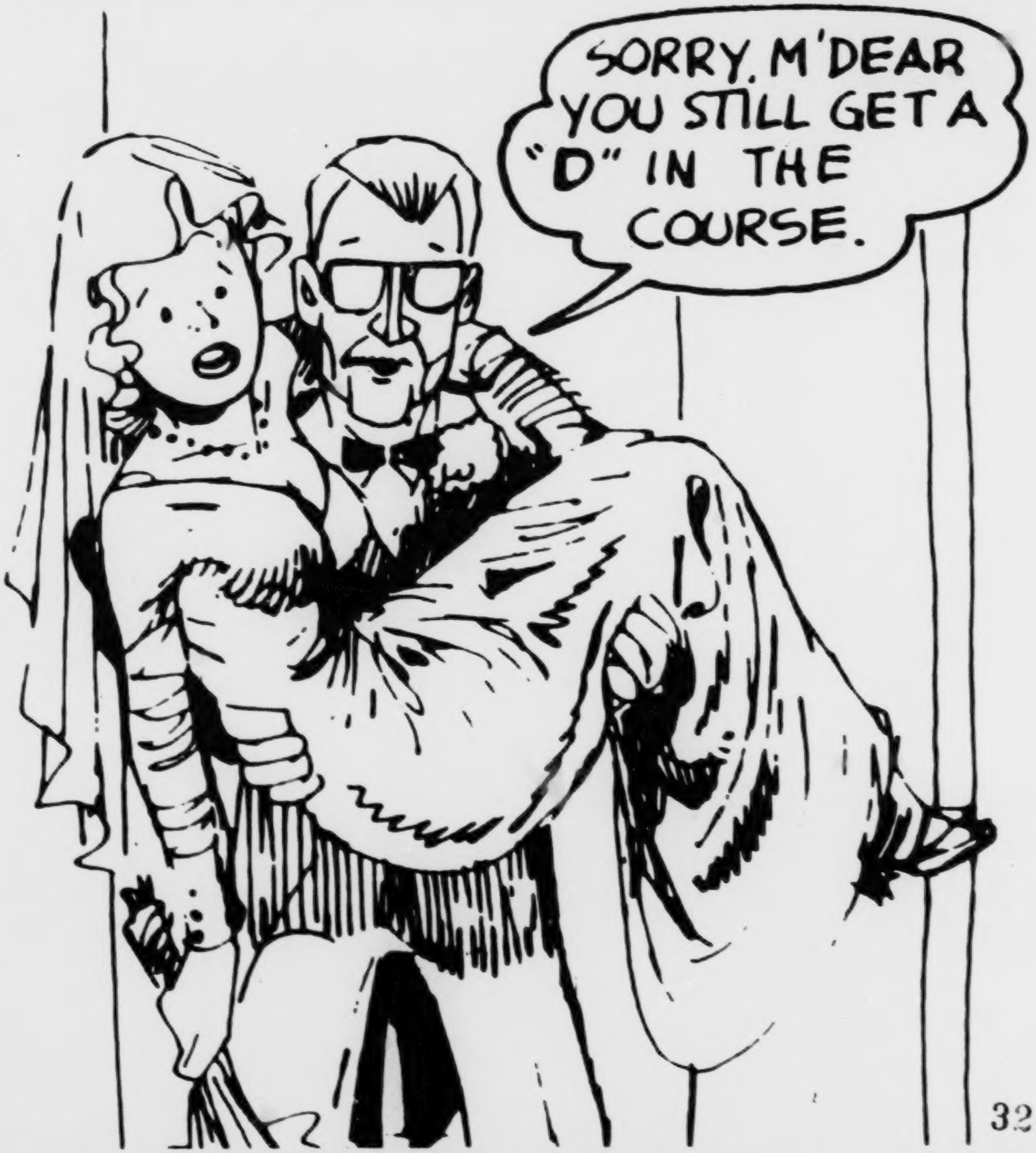
Type of Books

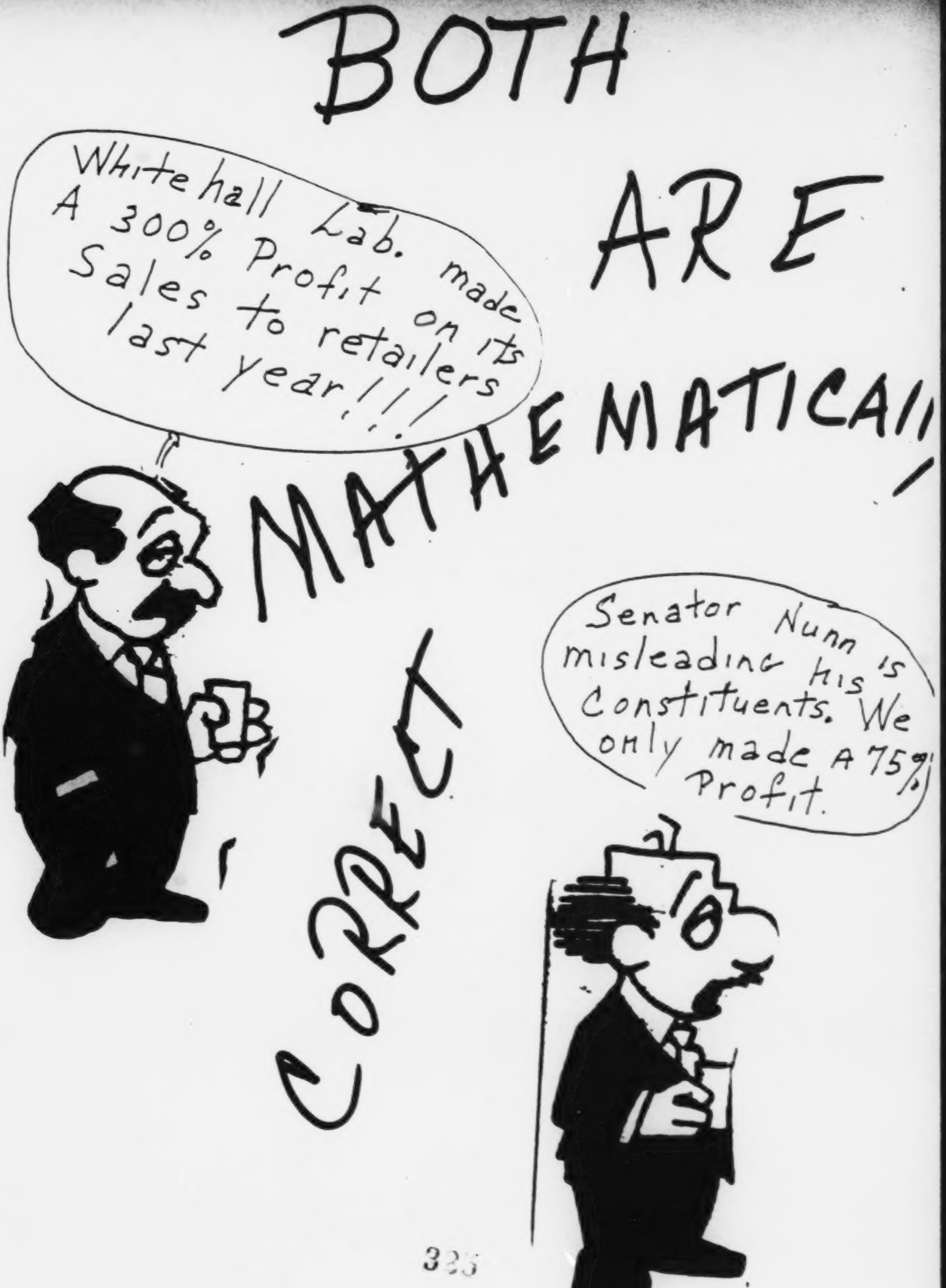
# *Flaws and Fallacies*

## Flaws and Fallacies

Percent, as a statistical measure, has been used more often or more effectively, or in a wider variety of ways to prop up wobbly arguments for years. You can improve or worsen any situation on paper as long as there are numbers around to be converted into percent.

Some decades ago Johns Hopkins University began admitting women to the university. The report came out that 33 1/3% of the women enrolled had married a faculty member. The story was not as impressive when it was revealed that only three women were admitted and only one married a faculty member.


SORRY, M'DEAR YOU STILL GET A "D" IN THE COURSE.


BOTH ARE MATHEMATICALLY CORRECT
Whitehall Lab. made A 300% Profit on its Sales to retailers last year!!!!
Senator Nunn is misleading his Constituents. We only made A 75% Profit.

Male=30 Female=33
PG 2

Name: Weight, Height, & Gender of JPTA

N=63

| Weight | Height | Gender | Weight | Height | Gender |
|---|---|---|---|---|---|
| | | | | | |
| 138 | 65 | F | 260 | 77 | M |
| 130 | 61 | F | 130 | 68 | M |
| 145 | 67 | F | 170 | 75 | M |
| 142 | 67 | M | 159 | 69 | M |
| 152 | 68 | F | 140 | 68 | M |
| 136 | 67 | M | 140 | 68 | M |
| 179 | 63 | F | 125 | 60 | M |
| 130 | 67 | F | 175 | 69 | M |
| 180 | 65 | F | 149 | 69 | M |
| 154 | 64 | F | 180 | 70 | M |
| 135 | 66 | F | 132 | 67 | M |
| 190 | 71 | M | 160 | 67 | F |
| 175 | 72 | M | 135 | 61 | F |
| 110 | 63 | F | 163 | 67 | F |
| 135 | 71 | M | 155 | 67 | F |
| 125 | 62 | F | 140 | 60 | F |
| 140 | 65 | M | 250 | 68 | M |
| 185 | 70 | M | 136 | 68 | F |
| 120 | 62 | F | 135 | 64 | F |
| 139 | 63 | F | 135 | 67 | F |
| 155 | 69 | M | 132 | 64 | F |
| 181 | 72 | M | 120 | 68 | M |
| 240 | 69 | F | 212 | 73 | M |
| 160 | 65 | F | 220 | 71 | M |
| 153 | 71 | M | 185 | 65 | F |
| 180 | 69 | F | 130 | 67 | F |
| 250 | 72 | M | 117 | 66 | F |
| 145 | 64 | M | 165 | 66 | M |
| 112 | 61 | F | 127 | 60 | F |

Male=30 Female=33 Name Weight, Height, & Gender of JPTA N=63
PG 2

| Weight | Height | Gender | Weight | Height | Gender |
|---|---|---|---|---|---|
| 110 | 62 | F | 140 | 66 | F |
| 210 | 70 | F | 195 | 76 | M |
| 280 | 76 | M | | | |
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| | | | | | |
| | Mw = 158.7 | | | | |
| | | Mh= 67.1 | | | |
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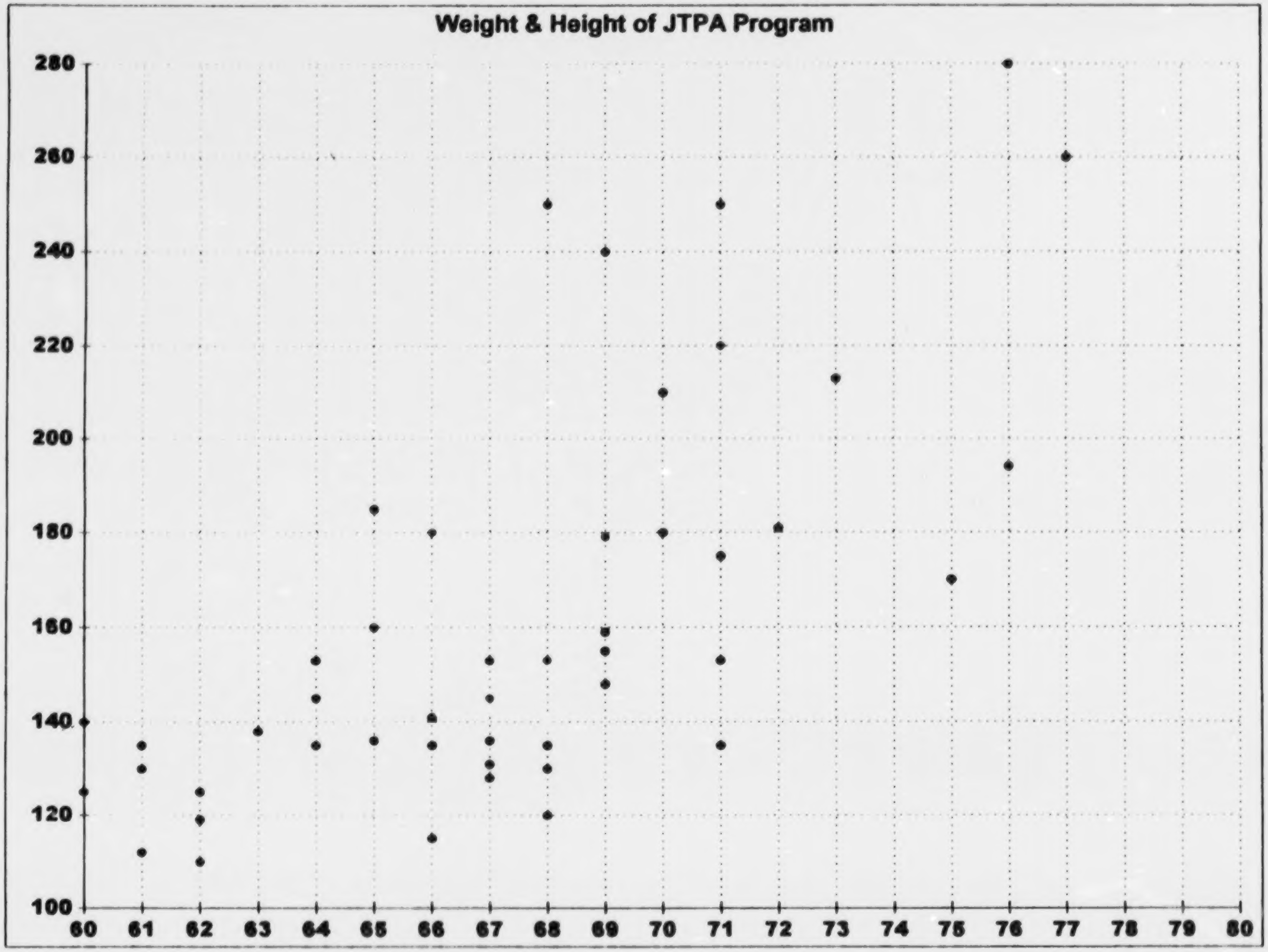
Weight & Height of JTPA Program
280
260
240
220
200
180
160
140
120
100
60
61
62
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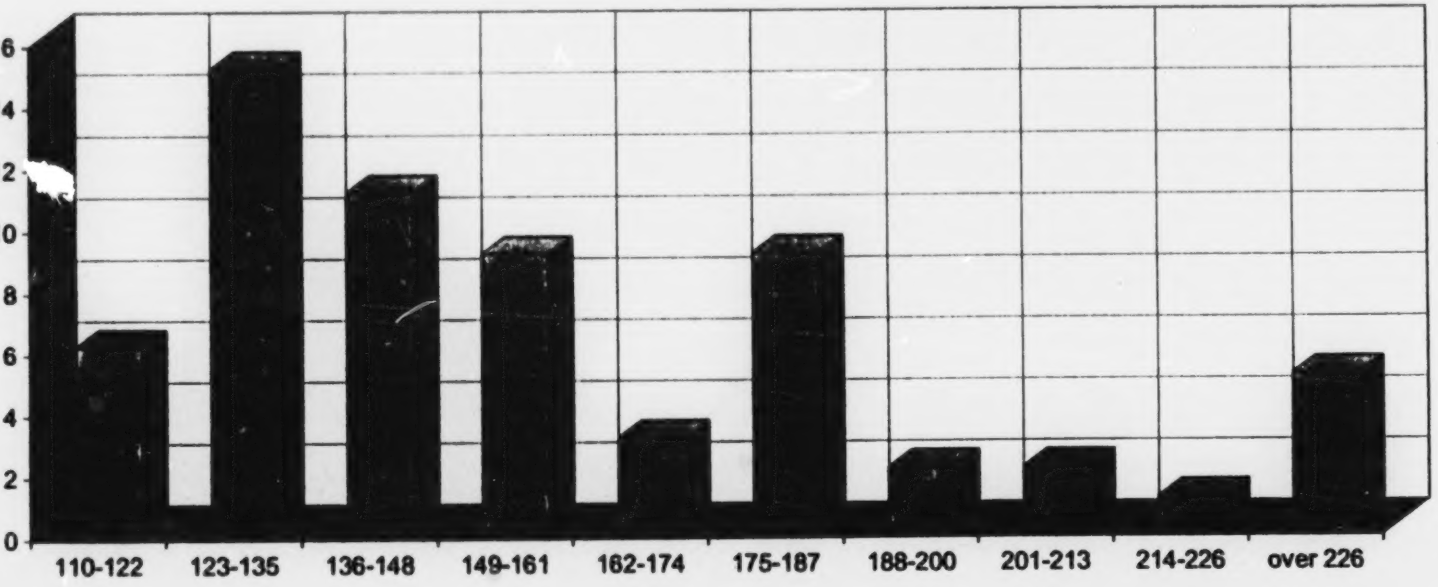
80

**Frequency Distribution of JTPA Program**



Males=30 Females=33

Name: Weight of JPTA

| Intervals | Tally | f | Cumf | Cumf % |
|---|---|---|---|---|
| 110-122 | 𝍸 / | 6 | 6 | 9 |
| 123-135 | 𝍸 𝍸 𝍸 | 15 | 21 | 33.3 |
| 136-148 | 𝍸 𝍸 / | 11 | 32 | 50.7 |
| 149-161 | 𝍸 //// | 9 | 41 | 65.1 |
| 162-174 | /// | 3 | 44 | 69.8 |
| 175-187 | 𝍸 //// | 9 | 53 | 84 |
| 188-200 | // | 2 | 55 | 87.3 |
| 210-213 | // | 2 | 57 | 90.4 |
| wt over 213 | 𝍸 / | 6 | 63 | 100 |

Males= Females= Name: Mean of Weights

| Intervals | Median | f | fx |
|---|---|---|---|
| 110-122 | 116 | 6 | 696 |
| 123-135 | 129 | 15 | 1935 |
| 136-148 | 142 | 11 | 1562 |
| 149-161 | 155 | 9 | 1395 |
| 162-174 | 168 | 3 | 504 |
| 175-187 | 181 | 9 | 1629 |
| 188-200 | 194 | 2 | 388 |
| 201-213 | 207 | 2 | 414 |
| Qugr 213(214-280) | 247 | 6 | 1482 |
| | | | |
| | | Σfx=10,005 | |
| | | m=10,005 | |
| | | 63 | |
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| | | | |
| | | | Mw=158.8 |
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Males-30 Females-33 Name : Height of JTPA

| Intervals | Tally | f | Cumf | Cumf % |
|---|---|---|---|---|
| 60-62 | 𝍸 \|\|\|\| | 9 | 9 | 14.3 |
| 63-65 | 𝍸 𝍸 \|\| | 12 | 21 | 33.3 |
| 66-68 | 𝍸 𝍸 𝍸 𝍸 \| | 21 | 42 | 66.6 |
| 69-71 | 𝍸 𝍸 \|\|\| | 13 | 55 | 87.3 |
| 72-74 | \|\|\|\| | 4 | 59 | 93.6 |
| 75-77 | \|\|\|\| | 4 | 63 | 100 |
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Sample Space
Male=   Female= 33

Name Weight, Height & Gender

N=33

| Weight | Height | Gender |
|---|---|---|
| 138 | 65 | F |
| 130 | 61 | |
| 145 | 67 | |
| 152 | 68 | |
| 179 | 63 | |
| 130 | 67 | |
| 180 | 66 | |
| 154 | 64 | |
| 135 | 66 | |
| 110 | 63 | |
| 125 | 62 | |
| 120 | 62 | |
| 139 | 63 | |
| 240 | 69 | |
| 160 | 65 | |
| 180 | 69 | |
| 117 | 66 | |
| 112 | 61 | |
| 127 | 60 | |
| 110 | 62 | |
| 140 | 66 | |
| 210 | 70 | |
| 160 | 67 | |
| 135 | 61 | |
| 163 | 67 | |
| 155 | 67 | |
| 140 | 60 | |
| 136 | 68 | |
| 135 | 64 | |
| 135 | 67 | |
| 132 | 64 | |
| 185 | 65 | Mh= 64.9 |
| 130 | 67 | Mw= 142.5 |

Sample Space
Male= 30 Female=

Name Weight. Height & Gender

N=30

| Weight | Height | Gender |
|---|---|---|
| 142 | 67 | |
| 136 | 67 | |
| 190 | 71 | |
| 175 | 72 | |
| 135 | 71 | |
| 140 | 65 | |
| 185 | 70 | |
| 155 | 69 | |
| 181 | 72 | |
| 153 | 71 | |
| 250 | 72 | |
| 145 | 64 | |
| 165 | 66 | |
| 195 | 76 | |
| 280 | 76 | |
| 260 | 77 | |
| 130 | 68 | |
| 170 | 65 | |
| 159 | 69 | |
| 140 | 68 | |
| 140 | 68 | |
| 125 | 60 | |
| 175 | 69 | |
| 149 | 69 | |
| 180 | 70 | |
| 132 | 67 | |
| 250 | 68 | |
| 120 | 68 | |
| 212 | 73 | |
| 220 | 71 | |
| | | |
| | | $M_h = 69.3$ |
| | | $M_w = 172.8$ |

# PEARSON r

The relationship between two variables can be demonstrated by two methods: Correlation coefficient (visualized by scatter gram) and Regression analysis(provides an equation that estimates the change in a dependent variable per unit change in an independent variable.

Pearson r measures the degree of closeness of the linear relationship between two variables. It always lie between 1 and -1. Positive values of r indicate a tendency of x and y to increase together. Negative values of r indicate large values of x are associated with small values of y.

When low correlations are found, one may be quick to conclude that there is little or no relationship between the two variables under study. However, the Pearson r shows only the linear relationship between two variables. Our failure to find evidence of a relationship maybe because of (1) The variables are unrelated or (2) The variables are related in a non linear fashion.

Males- Females- Name: Mean of Heights

| Intervals | Median | f | fx |
|---|---|---|---|
| 60-62 | 61 | 9 | 549 |
| 63-65 | 64 | 12 | 768 |
| 66-68 | 67 | 21 | 1407 |
| 69-71 | 70 | 13 | 910 |
| 72-74 | 73 | 4 | 292 |
| 75-77 | 76 | 4 | 304 |
| | | | |
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| | | | Σfx=4230 |
| | | | Mh=4230 |
| | | | 63 |
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| | | | Mh=67.1 |
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## PRACTICE WORK SHEET

DIRECTIONS : Use the frequency distribution table to answer the following questions.

1. How many students weighed between 123 and 135 pounds ?

2. What percent of students surveyed weighed 174 pounds or less?

3. How many students surveyed weighed more than 200 pounds?

4. How many students surveyed weighed less than 200?

5. out of all students surveyed, what percent weighed more than 226 pounds?

6. How many students weighed more than 187 pounds?

7. Consider the following data :

6,8,7,6,6,5,8,8,9,3,3,3,8,9,7,8,9,6,6,7,4,6,6,and 7

Make a frequency table which consist of:

Intervals

Tally marks

Frequency

cummulative frequency

Cummulative frequency percent

Sample Space
Male= Female=

Name Weight, Height & Gender

N=

| Weight | Height | Gender |
|---|---|---|
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No. Males- No. Females- Name: ____

| Intervals | Median | f | fx |
|---|---|---|---|
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| | | 342 | |
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| | 342 | | |

No. Males-    No. Females -    Name: ________________

| Intervals | Tally | f | Cumf | Cumf % |
|---|---|---|---|---|
| | | | | |
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# Cross Sectional Study

*Which Would You Choose?*

(D. Armstrong)

A young basketball player's main vein was cut while slam-dunking the ball on a glass basketball goal. He lost an enormous amount of blood and was facing death. The only blood available was taken from an HIV positive person. NOTE: Great strides have been taken in discovering a vaccine to eradicate AIDS or at most improve the quality of life for AIDS patients.

Would you .........

A. Refuse the blood and die immediately?

B. Take the blood with a guarantee of two years of normal life and after two years, long suffering before death?

JTPA Participants

N=110

62 Players
48 nonplayers

choices

| | A | B | |
|---|---|---|---|
| + | 52 | 10 | a+b=62 |
| basket ball − | 16 | 32 | c+d=48 |
| | a+c=68 | d+b=42 | |

Absolute Risk for Players = $\frac{a}{a+b} = \frac{52}{62} = 83.9\%$

Absolute Risk for nonplayers = $\frac{c}{c+d} = \frac{16}{48} = 33.3\%$

According to this study, 83.9% of the players polled would rather die immediately as opposed to 33.3% of non-players.

Relative Risk $\frac{a}{a+b} / \frac{c}{c+d} = \frac{839}{333} = 2.5$

therefore, relative to non-players, players are 2.5 times as likely to choose to die immediately based on this study.

Attribution Risk =
incidence among players -- incidence of non-players
Att Risk = 83.9 - 33.3 = 50.6

Often attributable risk is expressed as attributive risk percent, where attributable risk is a percentage of the absolute risk of players.

Att Risk of = $\frac{\text{Att Risk}}{\text{abs risk}}$ (players)

$= \frac{506}{839} = 100$

$\doteq$ 60%

Therefore, 60% of the time, the difference in the incidence of the choices between those who were at risk and those who were not at risk maybe directly attributable to the percent of the risk factor in this study.

# Quitlet Index of Obesity

Convert weight into Kg

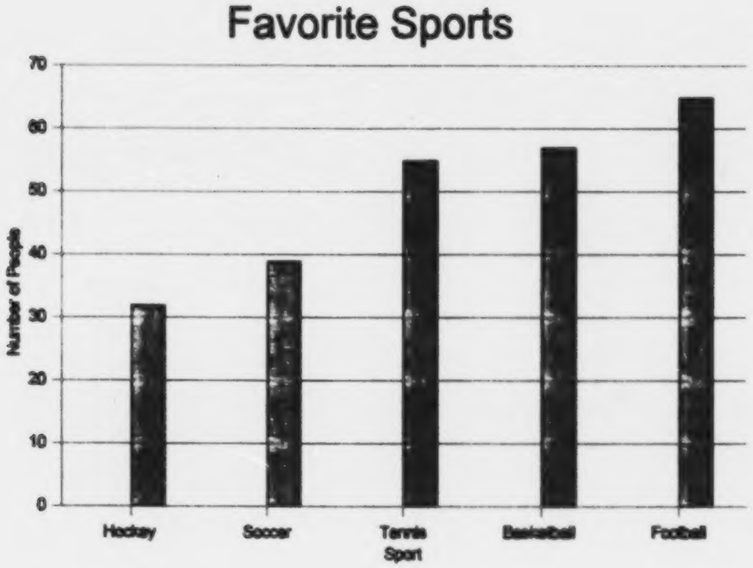
Convert height into Meters

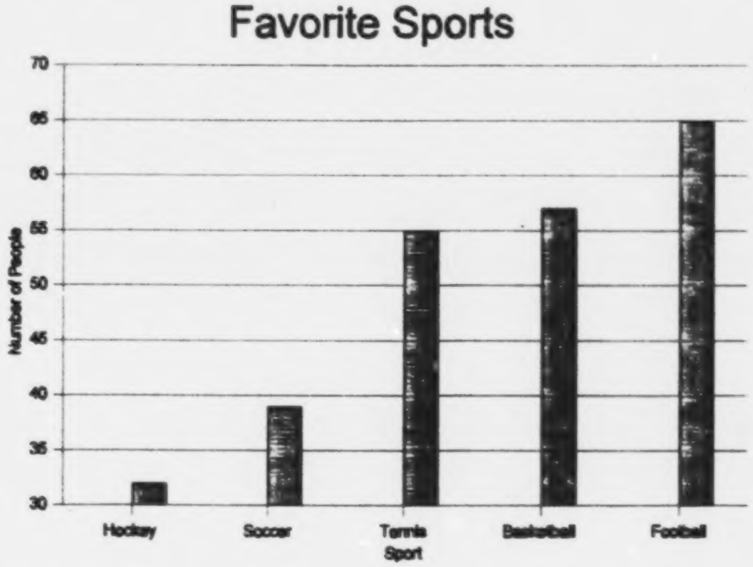
$$QI = \frac{W_{kg}}{(H_m)^2}$$

Range:

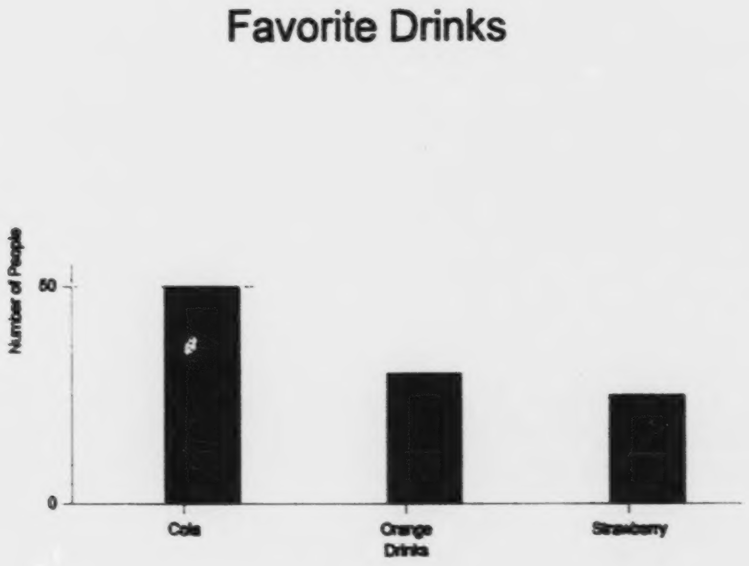
| | |
|---|---|
| Less than 20 | (under weight for height) |
| 20-24 | optimal |
| 24-28 | overweight |
| Greater 28 | obese |

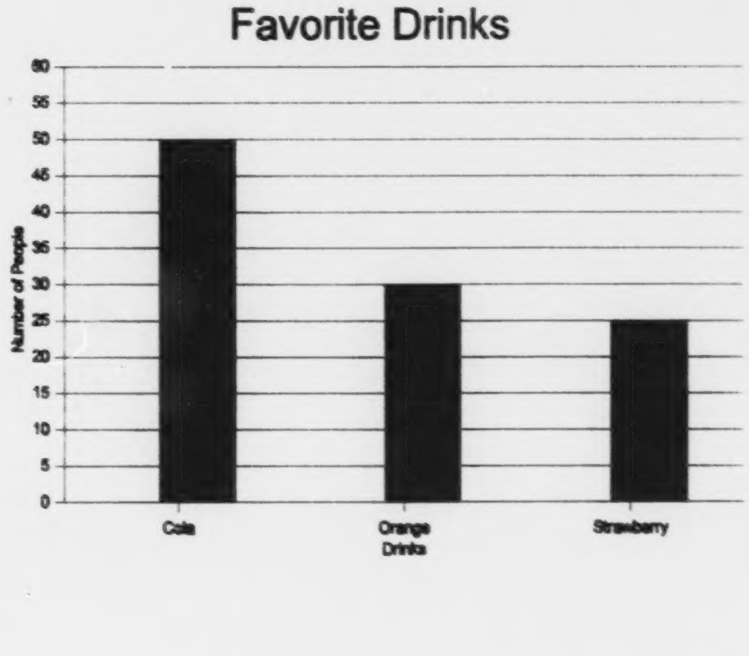
# Manipulative Axis





# The Manipulative Axis


Favorite Drinks


Favorite Drinks

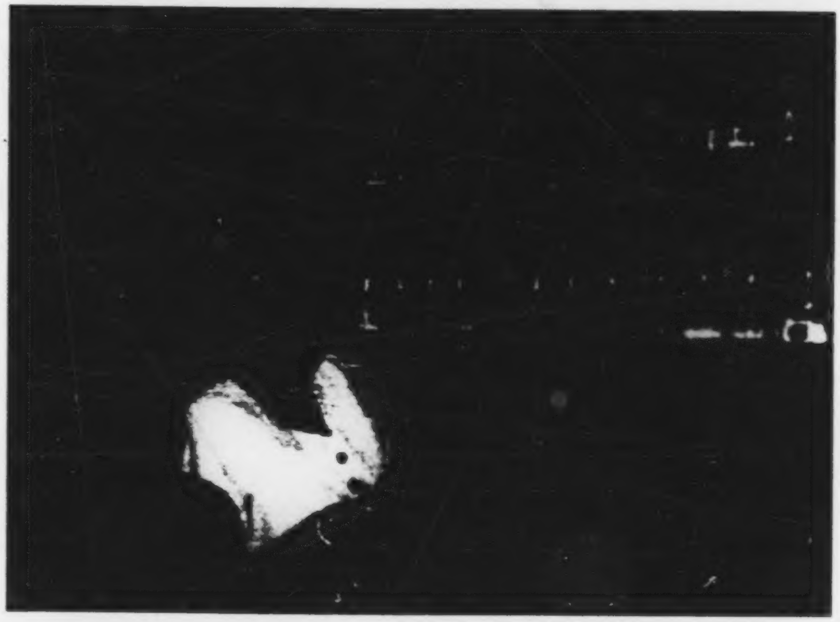
## Kenneth Baratko
## Mathematics/Computer Science
## Jones Sr. High School, Houston ISD

**University of Texas Medical Branch, Galveston**

**Dr. William Buford, Mentor**

BEST COPY AVAILABLE

## Frances Beeson
## Biology/Physical Science
## Dickinson High School, Dickinson



**University of Texas Medical Branch, Galveston**
**Dr. Chandra Yallampalli, Mentor**

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# Curriculum Implementation Plan

TEACHER: Frances E. Beeson

SITE: University of Texas Medical Branch, Galveston, Texas 77555-1062

MENTOR: Dr. Chandra Yallampalli, D.V. M., Ph.D.

LAB PERSONNEL ASSISTING IN PROJECT:
Dr. Yuan-Lin Dong, M.D., Ph.D.
Dr. Li Fang, Ph.D.
Dr. Pandu R.R. Gangula, Ph.D.
Ms. Terri Chapa, Research Assistant

My summer research internship will help my teaching curriculum in the following ways:

(1) students will be able to see scientific method in use as they view abstracts in a content area of the Biology Curriculum, the endocrine system.

(2) students will use teamwork in the Cooperative Learning Lesson to learn new endocrine vocabulary words.

(3) students will view a new medical research field by applying some research laboratory principles and techniques while conducting a lab activity.

(4) as a teacher, I will be better informed in the content area especially as hormones relate to pregnancy and high blood pressure. I will also be better motivated because of a recharged battery as a result of the stimulation this experience provided.

GOALS: To improve the quality of learning by:

(1) becoming personally more informed and updated on the endocrine system.

(2) developing a high interest lesson for students on endocrinology as it relates to pregnancy.

(3) establishing a sense of teamwork by the use of a Cooperative Learning Lesson to learn the unfamiliar endocrinology vocabulary by use of flash cards and games in a structured team setting.

(4) developing a complete lesson any teacher could use to assist and enhance their teaching of a unit on the endocrine system.

(5) rewriting an abstract at a lower reading level for the practice of the reading portion of the Biology Exit Exam.

(6) providing graphs or charts for interpretation as practice for the Biology Exit Exam.

STRATEGIES:

(1) Learn endocrine vocabulary through teacher and student use of flash cards (list and definitions provided in CIP lesson).

(2) Reinforce vocabulary through the student use of a card game using vocabulary words and definitions following a "rummy" format where definitions is matched with vocabulary word for points.

(3) Use of Vocabulary Quiz (provided in CIP Lesson).

(4) Using teacher note information, lead students through a discussion of endocrinology as it relates to pregnancy. Discuss interpretation of graphs as they are used in this type of research. Discuss steps of Scientific Method as it applies to research.

(5) Students will read and answer questions related to the Endocrinology Abstract and graphs that are rewritten in the Biology Exit Exam format.

(6) Students will conduct an experiment using plants and hormones and following the Scientific Method. data will be collected, charted and appropriate documentation will be written in correct form.

# Endocrinology of Pregnancy

## What is endocrinology?

The study of hormones and their physiology (effects on other organs). This includes the study of the endocrine system, diagnosis and treatment of disorders of the glands of internal secretion (endocrine glands).

## What is pregnancy?

The condition of having a developing embryo or fetus in the body, after union of an ovum and spermatozoan. In women, duration of the pregnancy from conception to delivery is about 266 days. During this time, many hormonal changes occur in the mother and the developing fetus. Pregnancy is marked by cessation of the menstrual cycle, nausea on arising in the morning (referred to as morning sickness), enlargement of the breast, pigmentation of the nipples and progressive enlargement of the abdomen.(1)

## How does fertilization occur?

1) In fertile women, the egg (ovum) is released (ovulation) 12-16 days after the onset of the previous menses (menstrual cycle).

2) The ovum must be fertilized (by the sperm from the male), within 24-48 hours if conception is to result. Of the $200 \times 10^6$ sperm deposited during intercourse, only approximately 200 reach the distal uterine tube awaiting an ovum to reach the ampulla (flask shape organ).

3) 6 or 7 days later, when the conceptus is a blastocyst of 1000-10,000 cells, implantation in the uterus occurs.

4) After about 3 weeks of gestation, human chorionic gonadatropin (hCG) is detectable in maternal mother's serum.

5) Under the influence of hCG, the corpus luteum continues to secrete steroid hormones in increasing quantities. Without effective implantation and subsequent hCG production, the corpus luteum survives for only about 14 days after ovulation. (Failure would result in miscarriage).

6) Embryo - The derivities of the fertilized ovum that eventually become the offspring. In humans, the developing organism is from the end of the second week after fertilization to the end of

the eighth week. Beginning with the 9th week until birth, it is then called the fetus.

### What are the symptoms of pregnancy?

Symptoms include breast tenderness, fatigue, nausea, absence of menstruation, softening of the uterus, and a sustained elevation of basal body temperature. All of these symptoms are attributable to hormone production by the corpus luteum and the developing placenta.

### What are some of the major hormones of pregnancy?

Progesterone is essential for maintenance of early pregnancy, and withdrawal of progesterone leads to the termination of pregnancy.

The corpus luteum produce hormones which include: progesterone, 17-hydroxyprogesterone, and estradiol. After about the seventh week, the placenta has increased production of hormones until the corpus luteum is no longer essential. Another marker of corpus luteum function is the polypeptide hormone relaxin; a dipeptide mass of 6000 (similar to insulin). Relaxin and hCG become detectable at about the same time and continues to rise, reaching a maximum concentration during the first trimester. Then the concentration drops to approximately 20 percent and is constant for the remainder of the pregnancy. Relaxin ripens the cervix and acts with progesterone to inhibit uterine contractions.

### How does the growth factors play a part in the pregnancy?

The function of the placenta is to establish effective communication between the mother and the developing fetus while maintaining the immune and generic integrity of both individuals. Initially, the placenta functions autonomously however, the fetal endocrine system is sufficiently developed by the end of the first trimester to influence placental function, and provide hormone precursors to the placenta. From this time, it is useful to consider the conceptus as the fetal-placental unit.

Seven days after fertilization when implantation begins, the trophoblast invades the endometrium and two layers of developing placenta can be demonstrated. The syncytiotrophoblast adjacent to the endometrium is derived from the precursor cytotrophoblast and is a major source of hormone production.

The decidua is the endometrium of pregnancy. It is capable of synthesizing a variety of polypeptide hormones including prolactin (mPRL) and relaxin. Its source of prostaglandins during labor is certain.

hCG human chorionic gonadatropin:

1) first measurable product of the placenta

2) consists of 237 amino acids

3) 30% carbohydrate by weight

4) In early weeks of pregnancy, concentration of hCG doubles every 1.7 to 2 days. It provides an index of trophoblast function. Its concentration peaks at the tenth gestational week then declines in third trimester.

5) Production of hCG makes pregnancy test possible (earliest test is 8-14 days after ovulation).

6) The concentration of that found in the mother. However, there is evidence that fetal hCG is an important regulator of the development of the fetal adrenal and gonad during the first trimester.

7) Progesterone production: The placenta relies on maternal cholesterol as it substrate for progesterone production. 250-350 mg. of progesterone is produced daily by the third trimester. The maternal progesterone rises progressively throughout pregnancy and appears to be independent of factors that normally regulate steroid synthesis and secretion. Progesterone is necessary for establishment and maintenance of pregnancy. Lack may cause infertility and recurrent pregnancy loss.

8) Estrogen production by the placenta depends on circulating precursors from both fetal and maternal steroids.

***(Over head transparency chart)***

**How does the mother adapt to pregnancy?**

The "fetal-placental unit" acts as a "parasite". It manipulates the maternal "host" for its own gain but normally avoids imposing excessive stress that would jeopardize the "host" and thus the "parasite" itself.

The prodigious production of polypeptide and steroid hormones by the fetal-placental unit directly or indirectly results in physiologic adaptations of virtually every maternal organ system.

The mother's anterior pituitary gland hormones have little influence on pregnancy after implantation has occurred.

The thyroid gland becomes enlarged during the first trimester of pregnancy. Uptake of iodine by the thyroid is increased. These changes are due in large part to the increased renal clearance of iodine, which causes a relative iodine deficiency. Total serum thyroxine is elevated.

The maternal parathyroid gland must make some changes. The net calcium requirement imposed by fetal skeletal development is estimated to be about 30g by term. This is met by elevated serum levels of parathyroid hormone.

The nutritional demands of the fetus require alteration of maternal metabolic homeostatic control, which results in both structural and function changes in the maternal pancreas. The size of the pancreatic inlets increase. Basal levels of insulin are lower or unchanged in early pregnancy but increase during the second trimester. Thereafter, pregnancy is a hyperinsulinemic state. The increased concentration of insulin has been shown to be a result of increased secretion rather than decreased metabolic clearance.

The major role of insulin and glucagon is the control of concentrations of nutrients, specifically glucose, amino acids, and fatty acids. These concentrations are regulated during pregnancy primarily for fetal need, and pre- and postpartum feeding levels cause pancreatic responses that act to support the fetal economy. Insulin is not transported across the placenta but rather exerts its effects on transportable metabolites.

The normal result of pregnancy, then is to reduce glucose levels modestly but to reserve glucose for fetal needs while maternal energy requirements are met increasingly by peripheral metabolism of fatty acids. These energy changes are beneficial to the fetus and innocuous to the mother with adequate diet. Even modest fasting, however, causes ketosis, which is potentially injurious to the fetus.

**What hormonal changes are occurring to the fetus during gestation?**

All of the adult anterior pituitary hormones are extractable from the fetal adenohypophysis by 12 weeks. Hypothalamic hormones thyrotropin-releasing hormone (TRH), Gonadotropin-releasing hormone (GnRH) and somatostallin are present by 8-10 weeks. The direct circulatory connection between hypothalamus and pituitary develops later, with capillary initially visible at about 16 weeks..

Development of the gonads and adrenals during the first trimester appears to be directed by hCG rather than by fetal trophic hormones, and the development of the thyroid glands during the first trimester occurs independently of TSH production by the fetus.

During the second trimester, there is a marked increase in secretion of all of the anterior pituitary hormones, which coincides with maturation of the hypophyseal portal system. Gonadotropin production also increases, with the female achieving higher FSH levels in both pituitary and serum than does the male. The fetal gonadotropins do not direct the events of early gonadal development but are essential for normal development of the differentiated gonads and external genitalia.

Vasopressin and oxytocin (fetal posterior pituitary hormones, are demonstrable by 12-18 weeks in the fetal posterior pituitary gland and correlate with the development of their sites of production, the supraoptic and paraventricular nuclei. The hormone content of the gland increases toward term, with no evidence of feedback control. During labor, umbilical artery oxytocin is higher than umbilical vein oxytocin. It has been suggested that the fetal posterior pituitary may contribute to the onset or maintenance of labor.

The fetal thyroid gland develops at about the same stage in development as the pituitary. By 12 weeks the thyroid is capable of iodine-concentrating activity and thyroid hormone synthesis. During the second trimester, TRH, TSH, and free $T_4$ all begin to rise. The maturation of feedback mechanisms is suggested by the subsequent plateau of TSH at about 20 fetal weeks. At birth, conversion of $T_4$ and $T_3$ becomes demonstrable. Very little placental transfer of thyroid hormone occurs in physiologic concentrations. This prevents maternal thyroid disorders from affecting the fetal compartment but also prevents effective therapy for fetal hypothyroidism through maternal supplementation. The function of the fetal thyroid hormones appears crucial to somatic growth for successful neonatal adaptation.

The fetal parathyroid gland is capable of synthesizing parathyroid hormone by the end of the first trimester. Because the placenta actively transports calcium into the fetal compartment, the fetus remains relatively hypercalcemic throughout gestation. This contributes to the suppression of parathyroid hormone and fetal serum levels in the umbilical cord have been reported to be low or undetectable. Fetal serum calcitonin levels are elevated, enhancing bone accretion.

Fetal gonads, the testis, is a detectable structure by six fetal weeks. The interstitial, or leydig cells, which synthesize fetal testosterone, are functional at this same stage. The maximum production of testosterone coincides with maximal production of hCG by the placenta; binding of hCG to fetal testes with stimulation of testosterone release has been demonstrated. Other fetal testicular products of importance are the reduced testosterone metabolite dihydrotestosterone and muilerian duct inhibitory factor. Dihydrotestosterone is responsible for development of female internal structures. Little is known about fetal ovarian function.

## How does the endocrine control parturition (labor)?

In the last few weeks of a normal pregnancy, two processes signal approaching labor. Uterine contractions become more frequent and the cervix becomes softer and thinner. This process is known as effacement, or "ripening". The onset of labor is usually fairly abrupt with regular contractions every 2-5 minutes, leading to delivery in less than 24 hours. The key inciting event has eluded detection. The difficulty in identifying a single initiating event in human labor suggest that there is more than one.

Progesterone causes hyperpolarization of the myometrium, decreasing the amplitude of action potentials and preventing effective contractions. In various experimental systems, progesterone decreases alpha-adrenergic receptors, stimulates cAMP production, and inhibitis estrogen receptor synthesis, promotes the storage of prostaglandin precursors in the decidua and fetal membranes, and stabilizes the lysosomes containing prostaglandin-synthesizing enzymes. Estrogen opposes progesterone in these actions and may have an independent role in ripening the uterine cervix and promoting uterine contractility. Thus the estrogen-progesterone ratio may be an important parameter. It has shown that an increase in the estrogen-progesterone ratio increases the number of myometrial gap junctions. This finding may explain the coordinate, effective contractions that characterize true labor as opposed to ineffective contractions of false labor.

Oxytocin infusion is commonly used to induce or augment labor. Both maternal and fetal oxytocin levels increase spontaneously during labor. Data in animals suggest that oxytocin's role in initiation of labor is due to increased sensitivity of the uterus to oxytocin rather than increased plasma concentration of the hormone.

Prostaglandin $E_2$ will induce labor in most women in the third trimester. Prostaglandins are almost certainly involved in the maintenance of labor once it is established. They probably are important in initiating labor in some circumstances. They probably are part of the "final common pathway" of labor. Prostaglandin synthetase inhibitors abolish premature labor but their clinical usefulness has been restricted by their simultaneous effect of closing the ductus arteriosus, which can lead to fetal pulmonary hypertension. (2)

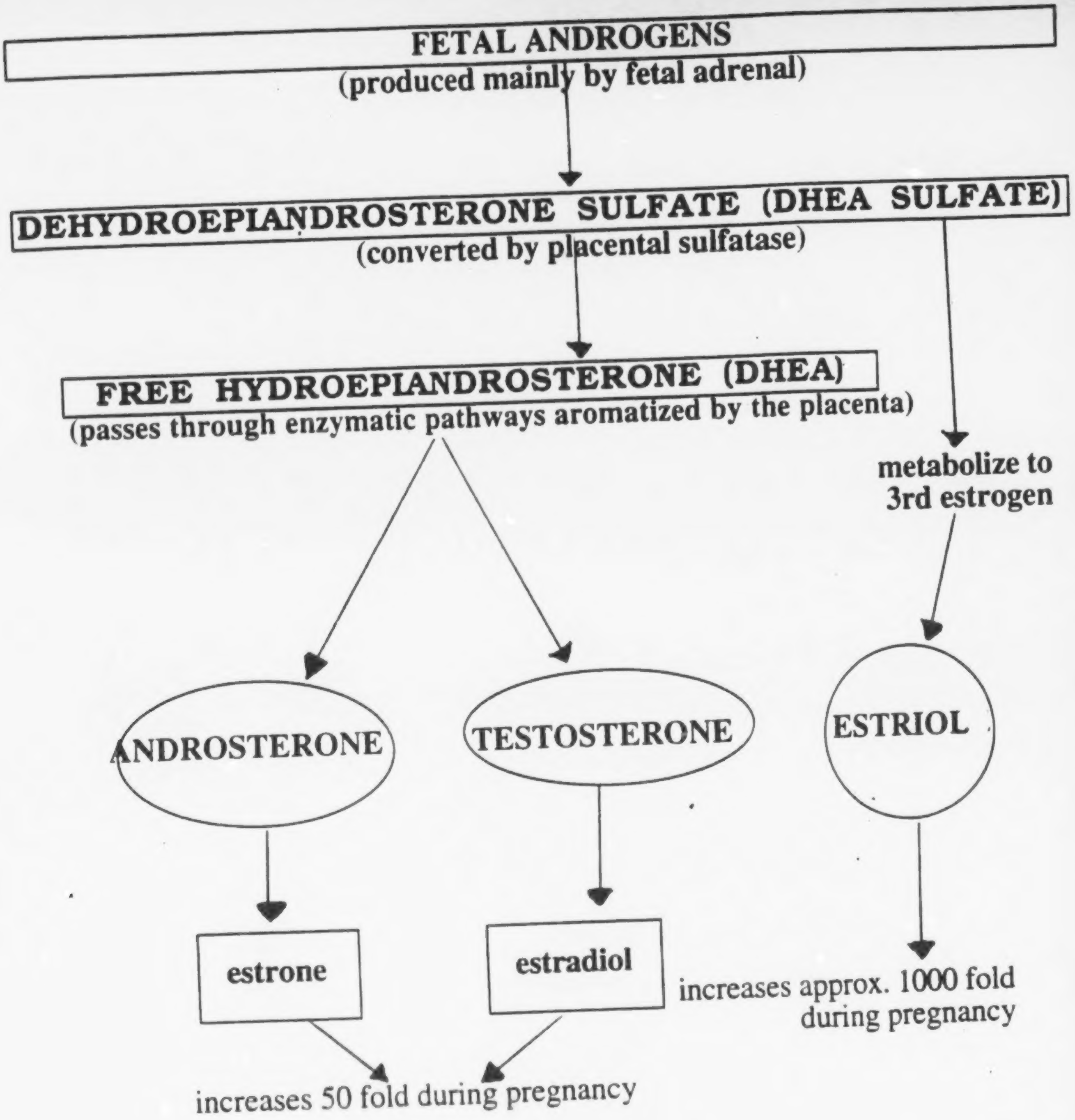
**How can pregnancy be prevented by hormones?**

Since the development of the oral contraceptive pill in 1951, the development of hormonal methods has continued; doses of steroids have been reduced and new oestrogens and progesterones have been introduced. Along with changes in the pill, the range of hormonal methods has been enlarged by long-acting formulations such as implants which enable continuous delivery of low doses of the drugs, thus avoiding peaks and troughs in circulating levels of steroids seen after oral pills. As a result, today's contraceptive hormone preparations have a higher degree of safety while remaining extremely effective when directions on dosage are followed explicitly. (3)

There are two basic types of hormonal contraceptives. One of these is a microcrystalline aqueous suspension of medroxyprogesterone acetate (Depro-Provera) by Upjohn.

The second is an oily solution of norethesterone enanthate (Nboristerat) by Schering A G

Both of these hormonal methods work by inhibiting the release of the ovum (ovulation)(4)



**FETAL ANDROGENS**
(produced mainly by fetal adrenal)

**DEHYDROEPIANDROSTERONE SULFATE (DHEA SULFATE)**
(converted by placental sulfatase)

**FREE HYDROEPIANDROSTERONE (DHEA)**
(passes through enzymatic pathways aromatized by the placenta)

**metabolize to 3rd estrogen**

ANDROSTERONE

TESTOSTERONE

ESTRIOL

**estrone**

**estradiol**

increases approx. 1000 fold during pregnancy

increases 50 fold during pregnancy

Measurements of estriol (serum or urinary) reflect fetal as well as placental function, integrity of fetal circulation and metabolism. It is the best available biochemical indicator of fetal well being. It can signal congenital derangements or iatrogenic intervention.

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2. Greenspan, F., *Basic and Clinical Endocrinology*, 3rd ed. Norwalk, CT; Appleton and Lang, 1991:543–566.

3. Von Hertzen, H. 1994. Hormonal Contraceptives for Women. *In* Current Concepts in Fertility Regulation and Production. C. Puri, Ed. Wiley Eastern Limited, New Age International Limited, New Delhi, 39–40.

4. Bialy, G., R. P. Blye. 1994. Role of Pharmacokinetics in the Development of Long-acting Contraceptive Drugs. *In* Current Concepts in Fertility Regulation and Production. C. Puri, Ed. Wiley Eastern Limited, New Age International Limited, New Delhi, 43–46.

# COOPERATIVE LEARNING VOCABULARY LESSON

## DIRECTIONS FOR CARD GAME

TEACHER: Using 3 X 5 index cards, place the vocabulary word on one card and the definition on a second card. The words and definitions may be duplicated (recommend on set per group of 4), cut apart and pasted from the list given.
It is helpful if each set is on a different color of card so the sets can be easily separated if they should get mixed up. I like to laminate the cards and to have a minimum of one set of cards for each four students in the class, if possible.

STUDENTS: Shuffle cards, deal cards.
if 2 players 12 cards
if 3 players 8 cards
if 4 players 7 cards
Put remaining cards in a pile face down for "drawing". Place one card face up. the object is to match the card with the definition (similar to Rummy)). You get 10 points for each pair. The person with the greatest number of points wins. The person to the right of the dealer begins.

FOLLOW THIS PROCESS

(1) Either "draw" a card from the stack OR take the card or cards from the discard stack. You may take more than one card in ORDER if it is available but you must play the LAST card you pick up.

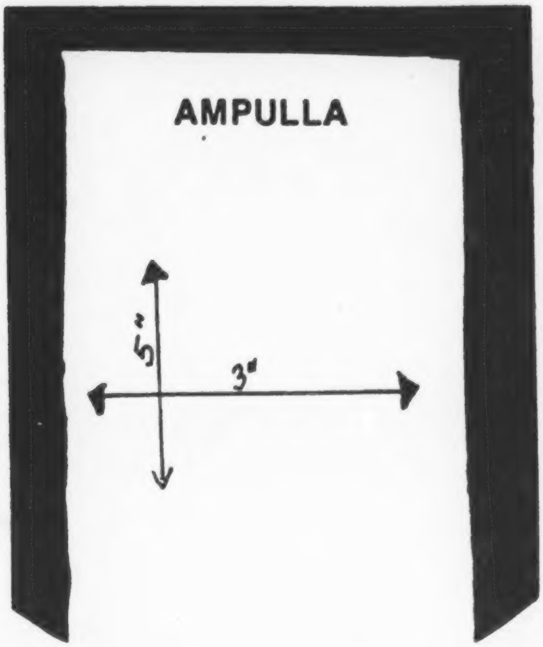
(2) Put down any pairs that you have face up.

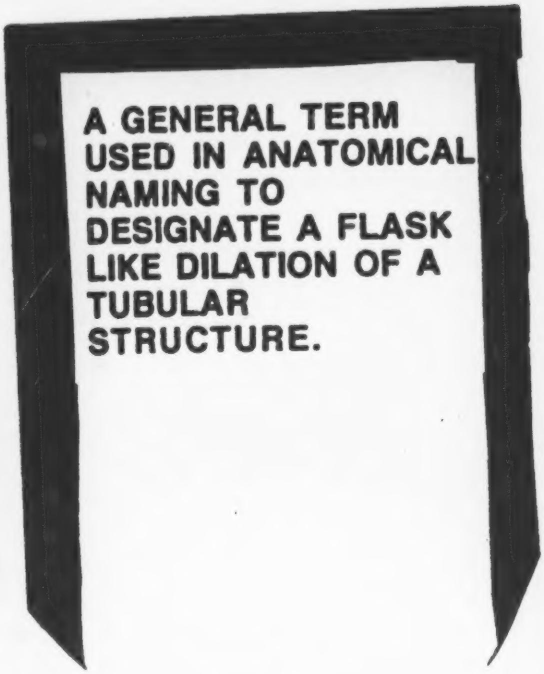
(3) Discard a card from your hand.

When you no longer have cards in your hand, you have "gone out". If you you have cards left in your hand when someone has "gone out", it cost you 5 points per card for each of the remaining cards. Subtract that from your pair total for your soore.

PAIRS SHOULD BE CHECKED TO BE SURE THEY ARE PAIRS BY A VOCABULARY LIST.

## SAMPLE CARD GAME CARDS




A GENERAL TERM USED IN ANATOMICAL NAMING TO DESIGNATE A FLASK LIKE DILATION OF A TUBULAR STRUCTURE.

## FLASH CARD DIRECTIONS

TEACHER: Using 5 X 8 Cards if possible, place the vocabulary word on one side of the card and the definition on the other side.

The teacher should go through the cards at least once with the class to help with pronunciations.

Place the students in Cooperative Learning groups.

STUDENTS: While working in groups, each student will assume responsibility for one task. Materials, timer, tester, recorder.

Each student in the group will take 5-10 cards (depending on the size of the group) at a time and learn them by going through them as we do with flash cards. Next upon command of the timer, cards are exchanged with partners. Partners test each other. The partners exchange cards and repeat the process until all the cards in the group are learned. Time keeper should call time every 5- 7 minutes depending on number of cards and teacher instruction. Tester for each group will then test each person on total number of cards while the recorder records the number gotten correct for each person for the teacher. Timer should keep the process moving. Recorder will give the scores to the teacher and the materials person will return the flash cards to the teacher and receive in exchange a set of playing cards to play the vocabulary card game.

## VOCABULARY

**AMPULLA**

A GENERAL TERM USED IN ANATOMICAL NAMING TO DESIGNATE A FLASK LIKE DILATION OF A TUBULAR STRUCTURE.

**AUTONOMOUSLY**

PERTAINING TO: THE STATE OF FUNCTIONING INDEPENDENTLY, WITHOUT EXTRANEOUS INFLUENCE

**CONCEPTUS**

THE SUM OF THE DERIVATIVES OF A FERTILIZED OVUM(EGG) AT ANY STAGE OF DEVELOPMENT FROM FERTILIZATION UNTIL BIRTH, INCLUDING EXTRAEMBRYOIC MEMBRANES AS WELL AS THE EMBRYO OR FETUS.

**BLASTOCYST**

THE MAMMALIAN CONCEPTUS IN THE POST-MORULA STAGE - HAS FLUID FILLED CAVITY WITH MORE THAN ONE GERM LAYER.

**CORPUS LUTEUM**

"YELLOW BODY" A YELLOW GLANDULAR MASS IN THE OVARY FORMED BY AN OVARIAN FOLLICLE THAT HAS MATURED AND DISCHARGED ITS OVUM. IF OVUM HAS BEEN IMPREGNATED, IT INCREASES IN SIZE AND PERSISTS FOR SEVERAL MONTHS. IF OVUM ISN'T IMPREGNATED, IT DEGENERATES AND SHRINKS. IT PRODUCES PROGESTERONE.

**DECIDUA**

THE ENDOMETRIUM OF THE PREGNANT UTERUS, ALL OF WHICH THE DEEPEST LAYER IS SHED AT PARTURITION.

**DISTAL**

DISTANT, REMOTE, FURTHER FROM ANY POINT OF REFERENCE

**ENDOMETRIUM**

THE INNER MUCOUS MEMBRANE OF THE UTERUS; THE THICKNESS AND STRUCTURE OF WHICH VARIES WITH THE MENSTRUAL CYCLE.

**FERTILIZATION**

THE ACT OF RENDERING GAMETES FERTILE OR CAPABLE OF FURTHER DEVELOPMENT. BEGINS WITH CONTACT BETWEEN A SPERMATOZOON AND AN OVUM; LEADING TO THEIR FUSION AND RESTORES THE DIPLOID NUMBER OF CHROMOSOMES - BIPARENTAL INHERITANCE AND DETERMINATION OF SEX. LEADS TO FORMATION OF ZYGOTE.

**GESTATION**

THE PERIOD OF DEVELOPMENT OF THE YOUNG IN VIVIPAROUS ANIMALS

FROM THE TIME OF FERTILIZATION OF THE OVUM UNTIL BIRTH.

HYPERTHYROIDISM

A CONDITION CAUSED BY EXCESSIVE PRODUCTION OF IODINATED THYROID HORMONES AND MARKED BY GOITER, TACHYCARDIA, ATRIAL FIBRILLATION, WIDENED PULSE PRESSURE, EXCESSIVE, SWEATING, WARM SMOOTH, MOIST SKIN, WEIGHT LOSS AND MUSCLE WEAKNESS.

HYPERTENSION

HIGH ARTERIAL BLOOD PRESSURE 140-200 mm Hg SYSTOLIC AND 90 DIASTOLIC. MAY HAVE NO KNOWN CAUSE - USUALLY ASSOCIATED WITH OTHER DISEASES.

HYPOTHYROIDISM

DEFICIENCY OF THYROID ACTIVITY. MOST COMMON IN WOMEN. CHARACTERISTICS; LOW BASAL METABOLISM, FATIGUE LETHARGY, SENSITIVITY TO COLD.

hCG

HUMAN CHORIONIC GONADTROPIN

INHIBIT

TO RETARD, ARREST OR RESTRAIN

MATERNAL

PERTAINING TO THE MOTHER

INTEGRITY

STATE OF BEING UNIMPAIRED. SOUNDNESS, COMPLETENESS, WHOLE.

IMPLANTATION

THE ATTACHMENT AND EMBEDDING OF THE FERTILIZED OVUM IN THE UTERINE WALL.

PARTURITION

PROCESS OF GIVING BIRTH TO A CHILD

PRECURSOR

SOMETHING THAT PRECEDES A SUBSTANCE FROM WHICH ANOTHER, USUALLY MORE ACTIVE OR MATURE SUBSTANCE IS FORMED. A SIGN OR SYMPTOM THAT HERALDS ANOTHER.

PRE-ECLAMPSIA

A COMPLICATION OF PREGNANCY CHARACTERIZED BY HYPERTENSION, EDEMA, AND/OR PROTEINURIA, WHEN CONVULSIONS AND COMA ARE ASSOCIATED, IT IS CALLED ECLAMPSIA.

PROGRESSIVELY

ADVANCING, GOING FORWARD; GOING FROM BAD TO WORSE; INCREASING IN SCOPE OR SEVERITY.

SERUM

THE CLEAR PORTION OF ANY BODY FLUID SUCH AS BLOOD.

SUBSTRATE

A SUBSTANCE UPON WHICH AN ENZYME ACTS. A SURFACE UPON WHICH A DIFFERENT MATERIAL IS DEPOSITED OR ADHERES SUCH AS A COATING OR LAYER.

SYNCYTIOTROBLAST

THE OUTER SYNCYTIAL LAYER OF THE TROPHOBLAST (BEGINNING OF THE EMBRYO)

VOCABULARY
AMPULLA

A GENERAL TERM USED IN ANATOMICAL NAMING TO DESIGNATE A FLASK LIKE DILATION OF A TUBULAR STRUCTURE.

AUTONOMOUSLY

PERTAINING TO: THE STATE OF FUNCTIONING INDEPENDENTLY, WITHOUT EXTRANEOUS INFLUENCE

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THE MAMMALIAN CONCEPTUS IN THE POST-MORULA STAGE - HAS FLUID FILLED CAVITY WITH MORE THAN ONE GERM LAYER.

CORPUS LUTEUM

"YELLOW BODY" A YELLOW GLANDULAR MASS IN THE OVARY FORMED BY AN OVARIAN FOLLICLE THAT HAS MATURED AND DISCHARGED ITS OVUM. IF OVUM HAS BEEN IMPREGNATED, IT INCREASES IN SIZE AND PERSISTS FOR SEVERAL MONTHS. IF OVUM ISN'T IMPREGNATED, IT DEGENERATES AND

SHRINKS. IT PRODUCES PROGESTERONE.

**DECIDUA**

THE ENDOMETRIUM OF THE PREGNANT UTERUS, ALL OF WHICH THE DEEPEST LAYER IS SHED AT PARTURITION.

**DISTAL**

DISTANT, REMOTE, FURTHER FROM ANY POINT OF REFERENCE

**ENDOMETRIUM**

THE INNER MUCOUS MEMBRANE OF THE UTERUS; THE THICKNESS AND STRUCTURE OF WHICH VARIES WITH THE MENSTRUAL CYCLE.

**FERTILIZATION**

THE ACT OF RENDERING GAMETES FERTILE OR CAPABLE OF FURTHER DEVELOPMENT. BEGINS WITH CONTACT BETWEEN A SPERMATOZOON AND AN OVUM; LEADING TO THEIR FUSION AND RESTORES THE DIPLOID NUMBER OF CHROMOSOMES - BIPARENTAL INHERITANCE AND DETERMINATION OF SEX. LEADS TO FORMATION OF ZYGOTE.

**GESTATION**

THE PERIOD OF DEVELOPMENT OF THE YOUNG IN VIVIPAROUS ANIMALS FROM THE TIME OF FERTILIZATION OF THE OVUM UNTIL BIRTH.

hCG

HUMAN CHORIONIC GONADTROPIN

HYPERTHYROIDISM

A CONDITION CAUSED BY EXCESSIVE PRODUCTION OF IODINATED THYROID HORMONES AND MARKED BY GOITER, TACHYCARDIA, ATRIAL FIBRILLATION, WIDENED PULSE PRESSURE, EXCESSIVE, SWEATING, WARM SMOOTH, MOIST SKIN, WEIGHT LOSS AND MUSCLE WEAKNESS.

HYPERTENSION

HIGH ARTERIAL BLOOD PRESSURE 140-200 mm Hg SYSTOLIC AND 90 DIASTOLIC. MAY HAVE NO KNOWN CAUSE - USUALLY ASSOCIATED WITH OTHER DISEASES.

HYPOTHYROIDISM

DEFICIENCY OF THYROID ACTIVITY. MOST COMMON IN WOMEN. CHARACTERISTICS; LOW BASAL METABOLISM, FATIGUE LETHARGY, SENSITIVITY TO COLD.

INHIBIT

TO RETARD, ARREST OR RESTRAIN

INTEGRITY

STATE OF BEING UNIMPAIRED. SOUNDNESS, COMPLETENESS, WHOLE.

IMPLANTATION

THE ATTACHMENT AND EMBEDDING OF THE FERTILIZED OVUM IN THE UTERINE WALL

MATERNAL

PERTAINING TO THE MOTHER

PARTURITION

PROCESS OF GIVING BIRTH TO A CHILD

PRECURSOR

SOMETHING THAT PRECEDES A SUBSTANCE FROM WHICH ANOTHER, USUALLY MORE ACTIVE OR MATURE SUBSTANCE IS FORMED. A SIGN OR SYMPTOM THAT HERALDS ANOTHER.

PRE-ECLAMPSIA

A COMPLICATION OF PREGNANCY CHARACTERIZED BY HYPERTENSION, EDEMA, AND/OR PROTEINURIA, WHEN CONVULSIONS AND COMA ARE ASSOCIATED, IT IS CALLED ECLAMPSIA

PROGRESSIVELY

ADVANCING, GOING FORWARD; GOING FROM BAD TO WORSE; INCREASING IN SCOPE OR SEVERITY.

**SERUM**

THE CLEAR PORTION OF ANY BODY FLUID SUCH AS BLOOD.

**SUBSTRATE**

A SUBSTANCE UPON WHICH AN ENZYME ACTS. A SURFACE UPON WHICH A DIFFERENT MATERIAL IS DEPOSITED OR ADHERES SUCH AS A COATING OR LAYER.

**SYNCYTIOTROBLAST**

THE OUTER SYNCYTIAL LAYER OF THE TROPHOBLAST (BEGINNING OF THE EMBRYO)

AMPULLA
AUTONOMOUSLY
CONCEPTUS
BLASTOCYST
CORPUS LUTEUM
INTEGRITY

378

BEESON 22

372

373

GESTATION

HYPER-
THYROIDISM

HYPERTENSION

HYPO-
THYROIDISM

hCG

INHIBIT

BEESON 23

379

374

375

IMPLANTATION

PARTURITION

PRECURSOR

PRE ECLAMPSIA

PROGRESSIVELY

MATERNAL

380

377

376

BEESON 24

SERUM

SUBSTRATE

SYNCYTIO-

TROBLAST

ENDOMETRIUM

FERTILIZATION

DECIDUA

DISTAL

378

379

BEESON 25

381

BEESON 28

## ENDOCRINOLOGY VOCABULARY TEST

Directions: Multiple Choice - select the best answer and place its letter on the scantron sheet by the appropriate number.

1. A GENERAL TERM USED IN ANATOMICAL NAMING TO DESIGNATE A FLASK LIKE DILATION OF A TUBULAR STRUCTURE.
   A. AUTONOMOUSLY B. CORPUS LUTEUM
   C. AMPULLA D. ENDOMETRIUM

2. THE MAMMALIAN CONCEPTUS IN THE POST-MORULA STAGE HAS FLUID FILLED CAVITY WITH MORE THAN ONE GERM LAYER.
   A. BLASTOCYST B. AMPULLA
   C. ENDOMETRIUM D. CORPUS LUTEUM

3. THE SUM OF THE DERIVATIVES OF A FERTILIZED OVUM(EGG) AT ANY STAGE OF DEVELOPMENT FROM FERTILIZATION UNTIL BIRTH, INCLUDING EXTRAEMBRYOIC MEMBRANES AS WELL AS THE EMBRYO OR FETUS.
   A. FERTILIZATION B. PARTURITION
   C. PRE-ECLAMPSIA D. CONCEPTUS

4. THE ENDOMETRIUM OF THE PREGNANT UTERUS, ALL OF WHICH THE DEEPEST LAYER IS SHED AT PARTURITION.
   A. GESTATION B. INHIBIT
   C. DECIDUA D. MATERNAL

5. THE ACT OF RENDERING GAMETES FERTILE OR CAPABLE OF FURTHER DEVELOPMENT. BEGINS WITH CONTACT BETWEEN A SPERMATOZOON AND AN OVUM; LEADING TO THEIR FUSION AND RESTORES THE DIPLOID NUMBER OF CHROMOSOMES- BIPARENTAL INHERITANCE AND DETERMINATION OF SEX. LEADS TO FORMATION OF ZYGOTE.
   A. FERTILIZATION B. CONCEPTUS
   C. PARTURITION D. SUBSTRATE

6. "YELLOW BODY" A YELLOW GLANDULAR MASS IN THE OVARY FORMED BY AN OVARIAN FOLLICLE THAT HAS MATURED AND DISCHARGED ITS OVUM. IF OVUM HAS BEEN IMPREGNATED, IT INCREASES IN SIZE AND PERSISTS FOR SEVERAL MONTHS. IF OVUM ISN'T IMPREGNATED, IT DEGENERATES AND SHRINKS. IT PRODUCES PROGESTERONE.
   A. ENDOMETRIUM B. CORPUS LUTEUM
   C. AMPULLA D. BLASTOCYST

7. THE INNER MUCOUS MEMBRANE OF THE UTERUS; THE THICKNESS AND STRUCTURE OF WHICH VARIES WITH THE MENSTRUAL CYCLE.
   A. AMPULLA B. AUTONOMOUSLY
   C. CORPUS LUTEUM D. ENDOMETRIUM

page 2 Vocabulary Test
8. DISTANT, REMOTE, FURTHER FROM ANY POINT OF REFERENCE
A. PRECURSOR B. PROGRESSIVELY
C. DISTAL D. SYNCYTIOTROBLAST

9. THE OUTER SYNCYTIAL LAYER OF THE TROPHOBLAST (BEGINNING OF THE EMBRYO)
A. PRECURSOR B. PROGRESSIVELY
C. DISTAL D. SYNCYTIOTROBLAST

10. A SUBSTANCE UPON WHICH AN ENZYME ACTS. A SURFACE UPON WHICH A DIFFERENT MATERIAL IS DEPOSITED OR ADHERES SUCH AS A COATING OR LAYER.
A. PRE-ECLAMPSIA B. SUBSTRATE
C. CONCEPTUS D. PARTURITION

11. A COMPLICATION OF PREGNANCY CHARACTERIZED BY HYPERTENSION, EDEMA, AND/OR PROTEINURIA.
A. PRE-ECLAMPSIA B. SUBSTRATE
C. CONCEPTUS D. PARTURITION

12. STATE OF BEING UNIMPAIRED. SOUNDNESS, COMPLETENESS, WHOLE.
A. HYPOTHYROIDISM B. HYPERTENSION
C. INTEGRITY D. IMPLANTATION

13. HIGH ARTERIAL BLOOD PRESSURE 140-200 mm Hg SYSTOLIC AND 90 DIASTOLIC. MAY HAVE NO KNOWN CAUSE-USUALLY ASSOCIATED WITH OTHER DISEASES.
A. INTEGRITY B. HYPERTENSION
C. HYPOTHYROIDISM D. IMPLANTATION

14. THE CLEAR PORTION OF ANY BODY FLUID SUCH AS BLOOD.
A. PROGRESSIVELY B. PRECURSOR
C. SERUM D. SYNCYTIOTROBLAST

15. SOMETHING THAT PRECEDES A SUBSTANCE FROM WHICH ANOTHER, USUALLY MORE ACTIVE OR MATURE SUBSTANCE IS FORMED. A SIGN OR SYMPTOM THAT HERALDS ANOTHER.
A. PROGRESSIVELY B. SYNCYTIOTROBLAST
C. SERUM D. PRECURSOR

16. PERTAINING TO: THE STATE OF FUNCTIONING INDEPENDENTLY, WITHOUT EXTRANEOUS INFLUENCE.
A. AUTONOMOUSLY B. AMPULLA
C. CORPUS LUTEUM D. ENDOMETRIUM

17. HUMAN CHORIONIC GONADTROPIN.
A. INHIBIT B. DECIDUA
C. hCG D. MATERNAL

18. TO RETARD, ARREST OR RESTRAIN
A. INHIBIT B. hCG
C. DECIDUA D. MATERNAL

19. ADVANCING, GOING FORWARD; GOING FROM BAD TO WORSE; INCREASING IN SCOPE OR SEVERITY.
A. SYNCYTIOTROBLAST B. SERUM
C. PRECURSOR D. PROGRESSIVELY

20. A CONDITION CAUSED BY EXCESSIVE PRODUCTION OF IODINATED THYROID HORMONES AND MARKED BY GOITER, TACHYCARDIA, ATRIAL FIBRILLATION, WIDENED PULSE PRESSURE, EXCESSIVE, SWEATING, WARM SMOOTH, MOIST SKIN WEIGHT LOSS AND MUSCLE WEAKNESS.
A. INTEGRITY B. HYPERTENSION
C. HYPOTHYROIDISM D. HYPERTHYROIDISM

21. DEFICIENCY OF THYROID ACTIVITY. MOST COMMON IN WOMEN. CHARACTERISTICS; LOW BASAL METABOLISM, FATIGUE LETHARGY, SENSITIVITY TO COLD.
A. INTEGRITY B. HYPERTENSION
C. HYPOTHYROIDISM D. HYPERTHYROIDISM

22. THE PERIOD OF DEVELOPMENT OF THE YOUNG IN VIVIPAROUS ANIMALS FROM THE TIME OF FERTILIZATION OF THE OVUM-UNTIL BIRTH.
A. GESTATION B. INHIBIT
C. DECIDUA D. MATERNAL

23. PERTAINING TO THE MOTHER
A. GESTATION B. INHIBIT
C. DECIDUA D. MATERNAL

24. PROCESS OF GIVING BIRTH TO A CHILD
A. PRE-ECLAMPSIA B. CONCEPTUS
C. PARTURITION D. FERTILIZATION

25. THE ATTACHMENT AND EMBEDDING OF THE FERTILIZED OVUM IN THE UTERINE WALL.
A. INTEGRITY B. HYPERTENSION
C. HYPOTHYROIDISM D. IMPLANTATION

# ANSWER KEY TO ENDOCRINOLOGY VOCABULARY TEST

1. C
2. A
3. D
4. C
5. A
6. B
7. D
8. C
9. D
10. B
11. A
12. C
13. B
14. C
15. D
16. A
17. C
18. A
19. D
20. B
21. C
22. A
23. D
24. C
25. D

# HORMONES USED IN THE REPRODUCTIVE PROCESS IN PLANTS

## LABORATORY

(NOTE THIS LAB SHOULD BE STARTED AT LEAST THREE WEEKS PRIOR TO STUDYING HORMONES)

The purpose of this lab is to determine if cuttings of plants are treated with plant hormone such as Rootone will develop root systems faster than plants not treated with the hormone.

Materials that you will use are 3 cuttings approximately 6 inches long with visible nodes (good choices of plants are Pathos Ivy or Scottish Ivy), small flower pots or other suitable containers (need holes in bottom for drainage), soil for pots, Rootone or other plant hormone and water. A grow light or sunshine is necessary.

Procedure:

(1) Cut cuttings approximately 6 inches long with visible nodes on each piece.

(2) Label containers, your name, hormone or no hormone and the date.
Don't forget to have a control.

(3) Dip one cutting in Rootone and plant 1-2 inches into soil.

(4) Plant cutting 2 and 3 without hormone.

(5) Water all plants and keep them moist during the entire experiment.

(6) Keep under grow light or in filtered sunlight (they love to be under a tree or on a porch if it is available).

(7) Check carefully after three weeks for root growth by **gently** removing the soil by placing the plant in a pan of water.

(8) Record your results.

TITLE: READING FOR BIOLOGY EXIT ANALYSIS PRACTICE

FROM: ABSTRACT INTERACTION BETWEEN NITRIC OXIDE AND PROSTAGLANDIN $E_2$ PATHWAYS IN PREGNANT RAT UTERI.

AUTHORS: YUAN-LIN DONG, M.D., PHD AND DR. CHANDRA YALLAMPALLI, D.V.M., PHD.

VOCABULARY: SEE HELPFUL VOCABULARY WORDS AT THE END OF THE READING

Doctors Dong and Yallampalli examined the possible interrelationships between nitric oxide (NO) and cyclooxygenase (COX) products in the uterus during pregnancy and labor.

As a result of this laboratory study, these observations were made.

(1) rat uteri during labor, at term (22nd day of gestation), demonstrated 69% decrease in nitrite production and 217% increase in prostaglandin $E_2$ ($PGE_2$)compared to day 18 of pregnancy.

(2) interleukin-1*B*(1L-1*B* ) induced a pronounced elevation of both nitrites and prostaglandin $E_2$ (PGE2)in the rat uteri,

(3) diethylenetriamine/NO, a donor of Nitric Oxide, induced a significant increase of $PGE_2$ production by the uterus in a dose dependent manner. (the increase of dose quantity caused a similar increase in production of $PGE_2$)

(4) $N^G$- Nitro-L-Arginine methyl ester, an inhibitor of NO(nitric oxide) synthesis markedly inhibited 1L-1*B* induced nitrite and $PGE_2$(prostaglandin $E_2$) production in the rat uteri: This inhibitory action was reversed by coincubation with L-arginine

(5) Exogenous $PGE_2$ significantly inhibited 1L - 1*B* induced but not constitutive, nitrite production.

(6).Inhibition of endogeneous $PGE_2$ (prostaglandin $E_2$ by indomethacin substantially increased nitrite production.

This would lead one to believe that there is an interaction between NO (Nitric Oxide) and COX pathways and this could be important in the regulation of uterine contractility during pregnancy and labor.

Nitric Oxide (NO) is a multifunctional molecule that mediates a number of diverse physiological processes. These include vasodilation neurotransmission , platelet antiaggregaton, cytostasis, and cytotoxicity.

Relaxation of vascular smooth muscle by nitrovasodilators is thought to be mediated by the increases of quanosine 3, 5 - cyclic monophosphate (cGMP) in smooth muscle cells.

Studies from our laboratory provide convincing evidence that NO generated from L-arginine by NO synthase (NOS) in the gravid uterus plays a role in maintaining uterine quiescence (calmness) during pregnancy but not during labor. We demonstrated the existence of an L- Arginine - NO-cGMP in the rat uterus and that the production of NO is up regulated during pregnancy and down-regulated during labor and postpartum (after delivery)

Present studies demonstrate that the decrease in NO production (69%) at term labor is accompanied by an increase (217%) in $PGE_2$ production by the uterus compared with that during day 18 of pregnancy. Furthermore, $PGE_2$ inhibits and indomethacin increases the 1L - 1B - stimulated NO production, whereas NO was stimulatory to $PGE_2$ production.

These results, together with our previous studies indicate that the NOS pathway is upregulated during gestation to maintain uterine quiescence and that an increase in $PGE_2$ production at term could attenuate uterine NO production, facilitating the initiation of labor. Therefore, the uterine NO and PG pathways may interact and these interaction could be important in the regulation of uterine contractility during pregnancy and labor.

Present studies confirm our earlier report that the uterine NO increases $PGE_2$ production by the rat uterus.

The underlying mechanisms controlling the NO and $PGE_2$ production by the uterus during pregnancy remains unclear. Our present studies suggest that both endogenous and exogenous NO increases $PGE_2$ production by the rat uterus.

In current experiments, the most significant finding is that the uterine NO production is substantially reduced by $PGE_2$. This was demonstrated both by the administration of exogenous $PGE_2$ and by the manipulation of endogenous $PGE_2$.

Exogenous $PGE_2$ inhibited 1L-1*B*-stimulated NO production, but failed to alter basal NO production, indicating that $PGE_2$ inhibits an inducible NOS(iNOS) in the uterus.

This is further supported by the observations that inhibition of endogeneous $PGE_2$ by indomethacin amplified the stimulatory effects of 1L-1*B* on NO production but no effect on basal NO generation by the uterus.

Therefore, it is tempting to speculate that increased $PGE_2$ at term could downregulate inducible NO production by the uterus, increasing contractility. Indeed, the pregnancy - associated increase and labor - associated decrease in uterine NO production appear to be through changes in iNOS content in the uterus.

This conclusion is based on studies in the rat and rabbit utilizing both NOS enzyme activity (biochemical)data and Western Immunoblotting (protein content) data on isoforms of NOS in the uterus .

A strong association between steroid hormones and uterine PG production in relation to pregnancy and labor is well recognized. Estradiol stimulates and progesterone inhibits $PGE_2$ production by the uterus and fetal membranes.

In summary, our studies with the rat demonstrate that:

(1) Uterine NO production is decreased at term labor, coinciding with increased $PGE_2$ synthesis;

(2) $PGE_2$ inhibits uterine 1L-1*B* - stimulated NO production, providing a potential mechanism to decrease NO production at term;

(3) NO stimulates $PGE_2$ synthesis. Because cytokines are elevated during pregnancy, the NOS and COX pathways may interact with each other, and the relation between the two pathways could be important in regulating uterine contractility and initiation of labor.

## References

I. Dong, Yuan-Lin, C. Yallampalli, 1996. Interaction between nitric oxide and prostaglanadin $E_2$ pathways in pregnant rat uteri, American Physiological Society,0193-1849/96.

# WORDS AND DEFINITIONS FOR USE WITH BIOLOGY EXIT EXAM READING PRACTICE

1. ATTENUATE - TO MAKE SMALL; TO REDUCE IN STRENGTH, AMOUNT, WEAKEN
2. cGMP - GUANOSINE 3'.5' - CYLIC MONOPHOSPHATE INCREASE IS THOUGHT TO CAUSE RELAXATION OF VASCULAR SMOOTH MUSCLE BY NITROVASODILATORS.
3. CONSTITUTIVE - MAKING A THING WHAT IT IS; ESSENTIAL
4. CONTRACTILITY - TO BECOME REDUCED IN SIZE-BY OR/AS IF DRAWN TOGETHER; SHRINK
5. CYTOSTASIS - THE CLOSURE OF CAPILLARIES BY WHITE BLOOD CORPUSCLES IN THE EARLY STAGES OF INFLAMMATION
6. CYTOTOXICITY - A TOXIN (POISON) OR ANTIBODY THAT HAS A SPECIFIC TOXIC ACTION UPON CELLS OF SPECIAL ORGANS.
7. DOSE DEPENDENT MANNER - THE INCREASE OF DOSAGE QUANTITY CAUSE A SIMILAR INCREASE IN THE PRODUCT MADE.
8. ENDOGENEOUS - PRODUCED FROM WITHIN, ORIGINATING FROM AN ORGAN OR PART.
9. DOWN-REGULATED - CAUSED TO PRODUCE LESS
10. EXOGENOUS - DERIVED OR DEVELOPED FROM EXTERNAL CAUSES. HAVING A CAUSE EXTERNAL TO THE BODY.
11. GRAVID - PREGNANT; HEAVY
12. INDUCED - TO STIMULATE THE OCCURRENCE OF, OR CAUSE. TO LEAD OR MOVE BY INFLUENCE OR PERSUASION

13. INDUCIBLE - POSSIBLE TO STIMULATE OR CAUSE TO OCCUR

14. INHIBITOR - A SUBSTANCE USED TO RETARD (SLOW DOWN) OR HALT AN UNDESIRABLE REACTION

15. INITIATION - TO BEGIN OR ORIGINATE

16. L-ARGININE - SUBSTANCE THAT REVERSES THE INHIBITIVE ACTION OF NO AND $PGE_2$ SYNTHESIS IN RAT UTERI CAUSED BY $N^G$ - NITRO - L - ARGININE METHYL ESTER

17. MARKEDLY - HAVING A NOTICEABLE, DISTINCTIVE TRAIT OR CHANGE; CLEARLY DEFINED

18. NEUROTRANSMISSION - A PROCESS BY WHICH A NEUROTRANSMITTER IS RELEASED, CROSSES THE SYNAPSE, AND AFFECTS THE ACTION OF THE TARGET CELL.

19. NO - NITRIC OXIDE

20. PLATELET ANTI AGGREGATION - PLATELETS(BLOOD) LACKING CLUMPING TOGETHER.

21. POSTPARTUM - OCCURRING IN THE PERIOD SHORTLY AFTER CHILD BIRTH.

22. SYNTHESIS - THE COMBINING OF SEPARATE ELEMENTS OR PARTS TO MAKE A WHOLE SUCH AS A COMPOUND.

23. SUBSTANTIALLY - CONSIDERABLE IN AMOUNT OR IMPORTANCE

24. UPREGULATED - CAUSED TO PRODUCE MORE

25. UTERINE QUIESCENCE - INACTIVE, STILL, CALM, UNMOVING UTERUS (NOT HAVING CONTRACTIONS)

26. VASODILATION - DILATION (EXPANSION) OF A BLOOD VESSEL.

QUESTIONS FOR PRACTICE OF THE READING PORTION OF BIOLOGY EXIT EXAM

DIRECTIONS: Multiple-Choice - select the best answer and placein the appropriate blank.

1. The statements labeled (1),(2),(3),(4),(5),(6), beginning on line_7___, is what step in Scientific Method.
   a. Problem or. objective
   b. Hypothesis
   c. Procedure
   d. Results
   e. Conclusion

2. The statement beginning on line_27___, Beginning with, " This would lead............. contractility during labor;" would be used in which step of Scientific Method.
   a. Problem or objective
   b. Hypothesis
   c. Procedure
   d. Results
   e. Conclusion

3. In lines 38-45 , this information would lead us to believe that NO
   a. would help keep down problems of early delivery or miscarriage
   b. would keep the baby from developing nervous disorders.
   c. would help the baby sleep better
   d. prevents the baby form being born on time.

4. In lines 42-45, of this reading, from the information gathered, if we interpret the data it appears.
   a. that the mother's body can't decide if the baby needs this hormone so it makes it sometimes, but not others-just as a precaution.

   b. the baby needs more NO during delivery so it makes more at this time.

   c. it makes more NO during the gestational period to prevent early contraction (labor pains) then decreases production at term as the baby is about to be born.

   d. it doesn't make NO as it's been found to be ineffective.

5. Why are rats used for this experiment
   a. because of availability
   b. because of likeness of reproductive organs and processes.
   c. because human trials always follow lower animal studies.
   d. all of the above.

# KEY

QUESTIONS FOR PRACTICE OF THE READING PORTION OF BIOLOGY EXIT EXAM

DIRECTIONS: Multiple-Choice - select the best answer and placein the appropriate blank.

1. The statements labeled (1),(2),(3),(4),(5),(6), beginning on line_7__, is what step in Scientific Method.
   a. Problem or objective b. Hypothesis
   c. Procedure [✓ d. Results] e. Conclusion
2. The statement beginning on line_27__, Beginning with, " This would lead............. contractility during labor;" would be used in which step of Scientific Method.
   a. Problem or objective b. Hypothesis
   c. Procedure d. Results [✓ e. Conclusion]
3. In lines 38-45 , this information would lead us to believe that NO
   [✓ a. would help keep down problems of early delivery or miscarriage]
   b. would keep the baby from developing nervous disorders.
   c. would help the baby sleep better
   d. prevents the baby form being born on time.
4. In lines 42-45, of this reading, from the information gathered, if we interpret the data it appears.
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   b. the baby needs more NO during delivery so it makes more at this time.

   [✓ c. it makes more NO during the gestational period to prevent early contraction (labor pains) then decreases production at term as the baby is about to be born.]

   d. it doesn't make NO as it's been found to be ineffective.

5. Why are rats used for this experiment
   a. because of availability
   b. because of likeness of reproductive organs and processes.
   c. because human trials always follow lower animal studies.
   [✓ d. all of the above.]

# Heather Lentz
## Composite Science
## Spence Middle School, Dallas ISD

## University of Texas Southwest Medical Center
## STARS Program
## Dr. Skip Garner, Mentor

# APPENDICES

## TEXAS TEACHER INTERNSHIP PROGRAM EVALUATION
## Summer 1996

## MENTORS

List at least two things that you and/or your department gained by hosting a teacher intern this summer.

- communicated an important program effectively.
- increased level of awareness as to the importance of individual performance.
- learned needs of local area and our plants.
- gained knowledge/insight into "The Life of a Middle School Science Teacher."
- I now have a liaison with an educator.
- Do projects which there isn't time to do during the academic year.
- Interface with the schools in Galveston & Harris Co.
- Teacher insight into education as we are making strategic decisions on this issue in our agency.
- Interviewing, interpretive, non-technical communicative skills of a teacher working objectively within an industrial setting.
- Teacher doing project that staff members do not have time to do in the academic year.
- Bringing a real classroom connection to our education projects.

Describe the development of the teacher's position (i.e. the job description/project from conception of the idea to implementation with the intern). Include information about changes that were made along the way and why.

- Knew need to communicate program –> described product needed –> set goal. Interviewed teachers & presented idea (found match). Need to include assistance to help with computer skills.
- Was behind in implementing program time-line. Turned program over to interns judgment and science expertise. Spent summer conferencing to bring program to near completion.
- We solicit expressions of interest from faculty throughout organization. Matched applications with openings.
- We knew we were going to do an internet-based project and chose the Teacher Internship Program as one mechanism to develop the project. The intern became a full team member in the project and has assumed a major role in developing/implementing the concept.
- Better direction/planning during first few weeks on internship.
- Pre-internship planning.
- Set up internship earlier.

Did the teacher fit into the natural flow of production/work in your facility?

| | |
|---|---|
| yes | 80% |
| no | 20% |

Please describe any transition problems that occurred during the first few weeks.

- Need to wait on upper management. Time for training - use of equipment such as Power Point, digital camera, etc.
- None
- One teacher had a composite program with three mentors, which was difficult to coordinate and is still disconnected.
- None

Were you involved in the interview/selection of the teacher intern?

| | |
|---|---|
| yes | 70% |
| no | 30% |

If yes, what was your involvement and how would you change this in the future.

- Presented idea of project. Determined qualification, interest, logistics, salary.
- Start placement earlier, involve assistant ASAP.
- Made the match between openings and teachers, and in some cases seek other openings to match certain teacher interests.
- Selected intern from a pool of about ten candidates. All were viable and would have done a good job.
- Team approach to interview/selection was very appropriate to this internship.

The following questions were offered as a pre-evaluation and post-evaluation.

| | | | Pre | Post | +/- |
|---|---|---|---|---|---|
| 1. | I believe it is important for teachers to require students to: | | | | |
| | a. | Work in groups. | 4.6 | 4.7 | .1 |
| | b. | Complete joint or group projects. | 4.3 | 4.7 | .4 |
| | c. | Give oral reports or presentations. | 4.7 | 4.5 | <.2> |
| | d. | Submit formal written reports. | 4.3 | 4.2 | <.1> |
| | e. | Do special projects or assignments on current issues or new developments in math, science or computer science. | 4.1 | 4.7 | .6 |
| 2. | I believe teachers' instruction should include information on: | | | | |
| | a. | New developments in subject area. | 4.6 | 4 | <.6> |
| | b. | Current research in subject area. | 4.6 | 4 | <.6> |
| | c. | State-of-the-art techniques in subject area. | 4.2 | 4.5 | .3 |
| 3. | I believe it is important for teachers to facilitate the integration of science, mathematics and technology in the classroom. | | 4.7 | 4.5 | <.2> |

| | | | | |
|---|---|---|---|---|
| 4. | I believe it is important for teachers to provide information about career options and educational requirements in math, science or computer science fields. | 4.7 | 4.5 | <.2> |
| 5. | I believe that teachers are keeping current on: | | | |
| a. | careers in math, science or computer science | 3.1 | 3 | <.1> |
| b. | technological advances | 2.8 | 3 | .2 |
| c. | the realities of the workforce | 3.1 | 2.6 | <.5> |
| d. | the advances in research | 3.1 | 3 | <.1> |
| 6. | I believe teachers should stress students' development/use of problem solving and higher order thinking skills in the classroom. | 4.6 | 5 | .4 |
| 7. | I believe it is important to utilize computers and other technologies in the classroom. | 4.6 | 4.5 | <.1> |
| 8. | It is my present understanding that teachers are maximizing the use of available resources in the classroom. | 2.7 | 3.5 | .8 |
| 9. | I believe that I have a clear understanding of the challenges teachers face today. | 3.1 | 3 | <.1> |
| 10. | I believe my teacher intern did return to the classroom with: | | | |
| a. | an increased knowledge of their content area. | 4.7 | 4.2 | <.5> |
| b. | an increased confidence in presenting current information to students and colleagues. | 4.7 | 4.2 | <.5> |
| c. | information concerning career opportunities/educational requirement that will assist in counseling students on careers in math, science and/or computer science fields. | 4.2 | 4.5 | .3 |
| d. | resources to enhance classroom instruction | 4.6 | 4.7 | .1 |
| 11. | I intend to continue a working relationship with my teacher intern, providing support, as necessary, during the school year. | 4.7 | 5 | .3 |

| | | | | |
|---|---|---|---|---|
| 12. | I believe that definite improvements in education did result from the collaboration of teachers and professional experts. | **4.8** | **4.7** | **<.1>** |

Comments/Suggestions:

- Conference calls between Alliance, prospective mentors and experienced mentors in similar fields.
- Need an assistant (in industry)/ work in a team.
- Two year project or one that will be finished by staff.
- Be a mentor - it will take time & commitment it is not an independent study project.
- Education of the program throughout upper management (visit with mentor's manager during orientation to get their buy-in/support).

# TEXAS TEACHER INTERNSHIP PROGRAM EVALUATION SUMMARY
## Summer 1996

### TEACHERS

| | |
|---|---|
| Male: | 2 |
| Female: | 10 |

| | | | |
|---|---|---|---|
| Black | 1 | Elementary | 1 |
| Caucasian | 10 | Middle | 5 |
| Hispanic | 0 | Secondary | 6 |

1. Please rate the values of your internship experience compared to other professional development experiences you have had.
Scale: 1 = low/poor . . . 5 = outstanding/excellence **4.5**

2. The best thing about my summer internship was ...
- developing fungi curriculum for my classroom and using new software to research it.
- the diversity - I really learned how very applicable critical thinking and problem solving skills I try to reinforce constantly -- are constantly and consistently valued in real life.
- the opportunity to be treated with respect, recognition of my value & expertise as an educator, opportunity to accumulate real world & technical knowledge, making new friends & networking and discovering the internet.
- working with multiply talented professionals.
- learning how to clean skulls & jawbones! Working with wonderful people at Texas Parks & Wildlife.
- freedom to learn and diversified my knowledge.
- contacts made for bringing new technology and equipment into the classroom.
- I was given the freedom to decide what to do with the information I learned i.e. I wasn't told I had to write something specifically.
- a chance to work professionally with other adults and a chance to have fun while working and earning a little money.
- the interaction between teacher and mentors -- being able to search on the computer -- learning how clinical researchers do research.
- it was a totally new environment for me. I've been in government agencies, companies, academic settings, but this was completely different.

3. The worst thing about my summer internship was ...
- no air conditioning in my building for 3 long days.
- so very many things to experience and so little time -- really there were no worst experience.
- lack of time.
- summer was too short.

- not enough time to do all the things I wanted to do.
- internal consulting, or at least I didn't find it, concerning some technical items.
- 100°F days in a tent -- very hot.
- at times I was frustrated because there wasn't a lot of contact between me and my coordinator i.e. I wasn't sure exactly what was expected of me.
- my seed experiment gave me a hard time and my computer went out at a bad time. The doctor who was very helpful was called "home" for 3 weeks to retrieve his family.
- by the time I was getting to know my way around and had defined jobs, it was time to leave.
- my assignment was clearly defined, but the implementation phase of it was not thought out.

4. The most important thing that I have gained (personally and/or professionally) from my internship experience was ...

- a greater level of computer literacy and refinement of pre-existing lab skills.
- my computer skills were enhanced and nurtured -- I feel not quite but almost comfortable with Power Point -- my resource base broadened tremendously. I also learned to roller-blade!
- ability to create science math & technology lab experiences based on new information & to acquire a mentor.
- tremendous wealth or resources -- personal and materials.
- Experience! All of the experiences cannot be matched.
- I will say a good groundwork for actually knowing what hardware/software to get as well as working on grant specifications.
- having and taking time to learn and organize new technology/ideas for making science more exciting and practical.
- what a researcher goes through daily i.e. I was able to identify with and observe others when things went wrong.
- recharged battery -- better knowledge of hormones, an opportunity to work with profused rats, an opportunity to think professionally again.
- how to do a simple studies.
- I did not realize the immensity of an industry such as Exxon, but I especially did not realize the diverse backgrounds necessary to keep such an operation running.

5. My job assignment was:

| | |
|---|---|
| Clearly defined | **4** |
| Appropriate for my background | **4.6** |
| Mentally stimulating/challenging | **4.9** |

6. My mentor was:

| | |
|---|---|
| Prepared for my arrival | 3.8 |
| Knowledgeable about the program | 3.5 |
| Supportive of my effort/work | 4.4 |
| Supportive of my curriculum plan | 4.3 |
| Helpful in my transition to the new environment | 4.2 |

7. Overall, my mentor/teacher relationship was:

| | |
|---|---|
| Professionally fulfilling | 4.1 |
| Effective for my growth | 4.2 |
| Contributed to the attaining of my goals for the internship | 4.2 |

General comments about your mentor/teacher relationship ...

- very organized, specific goals were set and reached, there was a lot of flexibility on the mentors part with respect to finished product.
- my mentors were personable and supportive -- we related on any levels -- I felt perfectly comfortable to approach them with any problem.
- my mentor, a former educator, was very supportive, non-restrictive, a coach, teacher -- he is the best -- most receptive to ideas.
- were available to me whatever I wanted and needed to do my job effectively.
- we were fast friends and will continue to work on educational tools together.
- very open and trusting.
- very good, would have been nice to be able to do broader "exploring" time in agency to get info on other work that may be helpful and applicable to my subjects. Could have used a better computer than then one I had.
- was very supportive but not present very often. Post doc could have cared less most of the time.
- his projects are wonderful and very successful, of course, this means that the demands on his time are great.
- my mentors were very supportive when I had questions, they were friendly and willing to help.
- the mentor I was working with was not involved in my project at all, the mentor who interviewed me and set up my project is an excellent chemist, but except for meetings hardly ever interacted with me.

| | |
|---|---|
| 8. Increased self-confidence | 3.9 |
| 9. Personal revitalization | 4.1 |
| 10. Renewed enthusiasm for teaching | 4.1 |
| 11. Increased knowledge of your teaching subject area | 4.4 |

| | |
|---|---|
| 12. Increased knowledge of practical applications within your subject area | 4.6 |
| 13. Increased knowledge in other related subject areas | 4.4 |
| 14. New perspectives on the teaching of your subject | 4.2 |
| 15. Increased knowledge of careers | 4.4 |
| 16. Increased knowledge of necessary skills and background required in the workplace | 4.6 |
| 17. Addition of new content to lessons of labs | 4.6 |
| 18. Revision of content within existing lessons | 4.4 |
| 19. Examples and applications from internship work (with necessary modifications of activities for your classroom) | 4.4 |
| 20. Lessons on careers and educational requirements | 4.2 |
| 21. Visits from your mentor and other professional from your internship site | 3.3 |
| 22. Providing opportunities for interaction between your students and professionals from your internship site | 3.5 |
| 23. Using materials and equipment from your internship site | 3.9 |
| 24. Sharing materials and resources with other teachers | 4.6 |
| 25. Sharing experience details and benefits/information with teachers and community members/groups | 4.6 |
| 26. Assigning projects based on "real-world" problems | 4.5 |
| 27. Having students working in groups | 4.5 |
| 28. Requiring students to complete group projects | 4.4 |
| 29. Requiring oral reports and group presentations | 4.8 |
| 30. Requiring formal written reports | 4.4 |

| | |
|---|---|
| 31. Integrating math, science and technology | **4.6** |
| 32. Integrating other subject areas | **4.3** |
| 33. Introducing new technology | **4.2** |
| 34. Using computer applications | **4.4** |
| 35. Emphasizing work habits (i.e. deadlines, neatness, etc.) | **4.3** |
| 36. Emphasizing laboratory safety | **4.1** |

The following questions were offered as a pre-evaluation and post-evaluation.

| | | | Pre | Post | +/- |
|---|---|---|---|---|---|
| 37. | I believe it is important for my students to: | | | | |
| | a. | Work in groups. | **3.9** | **4.5** | **.6** |
| | b. | Complete joint or group projects. | **3.9** | **4.4** | **.5** |
| | c. | Give oral reports or presentations. | **4.3** | **4.6** | **.3** |
| | d. | Submit formal written reports. | **4** | **4.5** | **.5** |
| | e. | Do special projects or assignments on current issues or new developments in math, science or computer science. | **4.5** | **4.6** | **.1** |
| 38. | In my classroom lectures or discussions, I believe it is important to refer to: | | | | |
| | a. | New developments in subject area. | **4.6** | **4.7** | **.1** |
| | b. | Current research in subject area. | **4.6** | **4.5** | **<.1>** |
| | c. | State-of-the-art techniques in subject area. | **4.6** | **4.3** | **<.3>** |
| 39. | I believe it is important to integration science, mathematics and technology in the classroom. | | **4.7** | **4.8** | **.1** |
| 40. | I believe it is important to provide my students with information about careers in math, science or computer science fields. | | **4.5** | **4.6** | **.1** |
| 41. | I believe that I am keeping current on: | | | | |
| | a. | careers in math, science or computer science | **3.4** | **4** | **.6** |
| | b. | technological advances | **3.5** | **4** | **.5** |
| | c. | the realities of the workforce | **3.9** | **4.4** | **.5** |
| | d. | the advances in research | **3.4** | **3.9** | **.5** |

| | | | | |
|---|---|---|---|---|
| 42. | I feel comfortable counseling students in possible careers in math, science or computer science fields. | 3.7 | 4 | .3 |
| 43. | I believe it is important to stress problem solving and higher order thinking skills of my students. | 4.6 | 4.7 | .1 |
| 44. | I believe it is important to utilize computers and other technologies in the classroom. | 4.5 | 4.6 | .1 |
| 45. | I am enthusiastic about teaching. | 4.7 | 4.9 | .2 |
| 46. | I believe that collaboration with industry professionals during the school year will enrich my classroom teaching. | 5 | 4.6 | <.4> |
| 47. | I intend to continue a working relationship with my mentor during the school year. | 4.1 | 4.2 | .1 |
| 48. | I believe that definite improvements in education will result from the collaboration of teachers and professional experts. | 4.6 | 4.9 | .3 |

# TEXAS TEACHER INTERNSHIP PROGRAM

## Intern Information List

## Summer 1996

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**NAME:** Ann T. Kelley
**ISD:** Houston ISD
**SCHOOL:** Stephen F. Austin High School
**PRINCIPAL:** Jose Treviño
**AREA(S):** Composite Science
**SPONSOR:** Exxon Chemical
5000 Bayway Drive
Baytown, Texas 77520
**MENTOR:** Dr. Brigitte Laki
713-425-5224
**HOME:** 1323 B West Pierce
Houston, Tx. 77019
**SCHOOL:** 1700 Dumble
Houston, Tx 77023
713-924-1600

**NAME:** Nancy McGreger
**ISD:** Victoria ISD
**SCHOOL:** Stroman High School
**PRINCIPAL:** Dr. Annette Scott
**AREA(S):** Biology/German
**SPONSOR:** Texas A&M University
Biochemistry Department
College Station, Tx 77843
**MENTOR:** Dr. Bruce McDonald
409-845-1491
**HOME:** 1505 Lova Dr.
Victoria, Tx 77901
**SCHOOL:** P.O. Box 1759
Victoria, Tx 77902
512-788-9804

**NAME:** Linda Rhoden
**ISD:** Pasadena ISD
**SCHOOL:** J.F. Dobie High School
**PRINCIPAL:** Jerry Speer
**AREA(S):** Composite Science
**SPONSOR:** Fina - Deer Park
P.O. Box 1200
Deer Park, Texas 77536
**MENTOR:** Lu Ann Kelly & Dr. Jose Sosa
409-884-0546
**HOME:** 1713 San Sebastion
Houston, Tx 77058-4103
**SCHOOL:** 11111 Beamer Rd.
Houston, Tx 77089
713-481-3000

**NAME:** Jennifer Willis
**ISD:** Pre-Service Teacher
**SCHOOL:**
**PRINCIPAL:**
**AREA(S):** Chemistry
**SPONSOR:** Texas A&M University
Center for Chemical
Characterization and Analysis
College Station, Tx 77843
**MENTOR:** Dr. E.A. Schweikert
409-845-2341
**HOME:** 12703 Jones Rd. #610
Houston, Tx 77070
**SCHOOL:**
**E-MAIL:** JENN4427@aol.com

**NAME:** Norene Rose Flaherty
**ISD:** Dallas ISD
**SCHOOL:** Long Middle School
**PRINCIPAL:** Alan Harris
**AREA(S):** Science
**SPONSOR:** TU Electric
1601 Bryan
Dallas, Texas 75266
**MENTOR:** Orlan Ihms
214-812-5097
**HOME:** P.O. Box 644
Midlothian, Tx 76065
**SCHOOL:** 6116 Reiger
Dallas, Tx 75214
214-841-5270

**NAME:** Dorothy Chavez
**ISD:** Round Rock ISD
**SCHOOL:** Gattis Elementary School
**PRINCIPAL:** Janell Sanders
**AREA(S):** Environmental Education
**SPONSOR:** Texas Parks & Wildlife
4200 Smith School Road
Austin, Texas 78744
**MENTOR:** Nancy Herron
512-389-4360
**HOME:** 4107 Mark Rae
Austin, Tx 78727
**SCHOOL:** 2920 Round Rock Ranch Rd
Round Rock, Tx 78664

# TEXAS TEACHER INTERNSHIP PROGRAM

## Intern Information List

## Summer 1996

**NAME:** Alan J. Cherepon
**ISD:** Round Rock ISD
**SCHOOL:** Westwood High School
**PRINCIPAL:** Linda Watkins
**AREA(S):** Composite Science
**SPONSOR:** Texas Parks & Wildlife
4200 Smith School Road
Austin, Texas 78744
**MENTOR:** Steve Hall/Scotty Oliver
512-389-4568
**HOME:** 2904 Martin Drive
Cedar Park, Tx 78613
**SCHOOL:** 12400 Mellow Meadows Dr.
Austin, Tx 78750
512-464-4000
**E-MAIL:** cherepona@tenet.edu

**NAME:** Vickie Smith
**ISD:** Austin ISD
**SCHOOL:** Fulmore Middle School
**PRINCIPAL:** Victoria Baldwin
**AREA(S):** Composite Science
**SPONSOR:** Texas Parks & Wildlife
Conservation Communications
Austin, Texas
**MENTOR:** Kathryn Hampton
805 N. Capital of Texas Hwy.
Wild Basin Preserve
**HOME:** 2505 Bowman Ave.
Austin, Texas 78703
**SCHOOL:** 204 E. Mary
Austin, Texas 78704
512-320-0111

**NAME:** Dina Armstrong
**ISD:** Galveston ISD
**SCHOOL:** Central Middle School
**PRINCIPAL:** Jack Stork
**AREA(S):** Mathematics
**SPONSOR:** UTMB-Galveston
Galveston, TX 77555
**MENTOR:** Dr. Todd Miller
**HOME:** 1115 Highway 146 #1303
Texas City, Tx 77590
**SCHOOL:** 3014 Ball Street
Galveston, Tx 77550

**NAME:** Kenneth Baratko
**ISD:** Houston ISD
**SCHOOL:** Jones Sr. High School
**PRINCIPAL:** Paralee Crawford
**AREA(S):** Mathematics/Chemistry
**SPONSOR:** UTMB-Galveston
362 Childrens Hospital
Galveston, Tx 77555
**MENTOR:** Dr. William Buford
409-772-2189
**HOME:** 8333 Nairn
Houston, Tx 77074-3825
**SCHOOL:** 7414 St. LO
Houston, Tx 77033
713-733-1111
**E-MAIL:** KDB62844@Jetson.UH.edu

**NAME:** Frances Beeson
**ISD:** Dickinson ISD
**SCHOOL:** Dickinson High School
**PRINCIPAL:** Mike LaTouche
**AREA(S):** Biology, Physical Science
**SPONSOR:** UTMB-Galveston
Galveston, Tx 77555
**MENTOR:** Dr. Chandra Yallampalli
**HOME:** 4909 Blue Water Lane
Dickinson, Tx 77539
**SCHOOL:** 3800 Baker Drive
Dickinson, Tx 77539
713-534-6800

**NAME:** Heather Lentz
**ISD:** Dallas ISD
**SCHOOL:** Spence Middle School
**PRINCIPAL:** Claudia Lozano
**AREA(S):** Composite Science
**SPONSOR:** STARS
University of Texas Southwest
Medical Center
5323 Harry Hines Boulevard
Dallas, Tx 75235
**MENTOR:** Dr. Skip Garner
**HOME:** 7150 E. Grand Ave., #1505
Dallas, Tx 75223
**SCHOOL:** 4001 Capital Dr.
Dallas, Tx 75204